PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P/61695/PC		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02188	07/06/2000	19/06/1999
International Patent Classification (IPC) or national classification and IPC H01P1/18		
Applicant MARCONI CASWELL LIMITED		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 10 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
16/01/2001	26.03.01
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Van der Peet, H Telephone No. +49 89 2399 2764

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02188

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
Description, pages:

1-17	as originally filed				

Claims, No.:

1-20	as originally filed				

Drawings, sheets:

1/10-10/10	as received on	09/08/2000	with letter of	03/08/2000	

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-20
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations
   see separate sheet

1. Document US-A-4710733 (hereinafter: document D2) discloses in figure 2 a phase-shifter comprising: phase altering-means (6) for introducing a phase shift into a signal (15) whose phase is to be controlled and an actuator (12B) which changes shape in response to an electrical control signal (8B), wherein the actuator is mechanically connected to the phase-altering means (6) such that the change in the shape of the former leads a phase-altering action in the latter. The features of the characterising portion of claims 1 and 17 are neither known from document D2 nor from patent document US-A-5504466 (hereinafter: document D1). The subject matter of claim 1 and of claim 17 is accordingly novel and cannot be rendered obvious by the technical teaching of documents D1 and D2.

INTERNATIONAL SEARCH REPORT

Inte ional Application No
PCT/GB 00/02188

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01P1/18 H01Q3/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01P H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
INSPEC, EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 504 466 A (CHAN-SON-LINT ET AL.) 2 April 1996 (1996-04-02) column 12, line 37 -column 13, line 15; figures 21A,B	1,17
A	US 4 710 733 A (CRILL ET AL.) 1 December 1987 (1987-12-01) column 1, line 12 -column 3, line 2; figures 1,2	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 September 2000	13/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Den Otter, A

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. ional Application No
PCT/GB 00/02188

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5504466 A	02-04-1996	FR 2706680 A	23-12-1994
		CA 1338792 A	10-12-1996
		GB 2288076 A,B	04-10-1995
US 4710733 A	01-12-1987	NONE	

INTERNATIONAL SEARCH REPORT

[redacted]ional application No.
PCT/GB 00/02188

Box III TEXT OF THE ABSTRACT (C ntinuation of item 5 f the first sheet)

LINE 8.THE WORD(CONFIGURED)IS SPELT WRONG,THE (N)IS MISSING
LINE 12.AFTER (26)DELETE UNTIL THE END.

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(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

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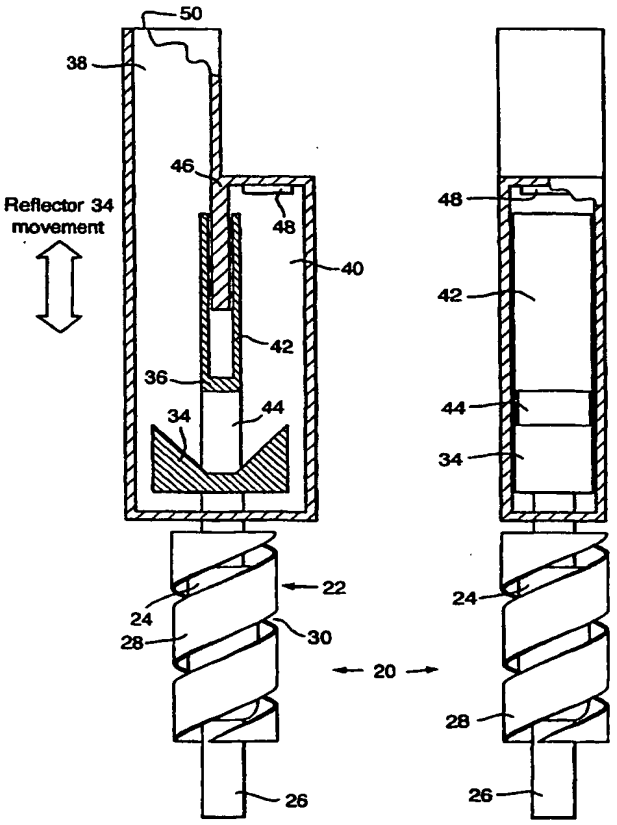
[Continued on next page]

(54) Title: STEERABLE PHASED ARRAY ANTENNA



(57) Abstract: A steerable phased array antenna has a plurality of antenna elements each having an associated phase-shifter. The phase-shifters have actuators which change shape in response to electrical signals and in so doing cause either a path length of signals to be radiated from the antenna elements to change or a propagation constant of a transmitting medium to change, thereby introducing phase shift into the respective signal. The actuators comprise tubular stator (22) of piezoelectric or magnetostrictive material; a piston (26) coaxially disposed within the stator and a bearing member (24) disposed between the stator (22) and piston (26) which are configured such that the stator (22) distorts in an approximately frustro-conical manner in response to said control signal thereby causing the bearing member (24) to roll axially along the stator (22) and the movement of the bearing member (24) in turn causing axial movement of the piston (26).

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IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

STEERABLE PHASED ARRAY ANTENNA

The present invention relates to a steerable phased array antenna and more especially to a phase shifter for use in such an antenna.

Electronically steerable phased array antennas are known and generally comprise an array of antennas each of which has an associated phase shifter which produces a controllable phase shift in a beam transmitted by the array. A signal to be transmitted is split into a number of individual in-phase sub-signals, each of which passes through an individual phase shifter in which it is phase shifted before it is supplied to one of the antenna elements and transmitted therefrom. Transmission of all of the sub-signals produces an overall array output in the form of the beam. The beam can be steered electronically by carefully selecting the phase shifts which are applied to the sub-signals.

For microwave applications, the phase shifters are typically fabricated in Gallium Arsenide (GaAs). There are a number of problems associated with the use of such solid state components. Typically a phase array antenna has an array of several thousand radiating elements requiring a correspondingly large number of phase shifters. Since such phase shifters are expensive, this makes the entire array expensive. Furthermore, GaAs phase shifters are lossy, having a loss of typically -6 dB in the X band (8-12.4 GHz), and this leads to dissipation of power in the array. To compensate for these losses it is known to provide a gain element, typically one amplifier for each phase shifter. Even with this gain, it is only possible to compensate for relatively low power losses, typically 20-30 dBm before non linearities caused by power compression occur. In addition, high power levels can cause permanent damage to conventional phase-

shifters, so that ideally amplification should be provided downstream of the shifters.

Steerable phased array antennas are used to transmit radiation, particularly microwave radiation. In this context microwave radiation covers the range 0.247 GHz to 100GHz and includes the Ka band (26.5 GHz to 40 GHz) and the millimetric band (30 GHz to 100 GHz).

According to a first aspect of the invention there is provided a phase-shifter comprising: phase-altering means for introducing a phase shift into a signal whose phase is to be controlled and an actuator which changes shape in response to an electrical control signal, wherein the actuator is mechanically connected to the phase-altering means such that the change in shape of the former leads to a phase-altering action in the latter; characterised in that the actuator comprises a tubular stator of piezoelectric or magnetostrictive material, a piston coaxially disposed within the stator and a bearing member disposed between the stator and piston, wherein the stator distorts in an approximately frustro-conical manner in response to said control signal thereby causing the bearing member to roll axially along the stator, the movement of the bearing member in turn causing axial movement of the piston.

In a preferred embodiment the stator comprises a piezoelectric tubular member having electrodes on the inside and outside for coupling to a source of the control voltage and the bearing member comprises an elastically deformable and approximately annular in cross-section. Advantageously the stator has a slot extending completely through the wall of the tubular member and which describes a helical path about the tubular member.

In one embodiment the phase-altering means comprises a reflecting member inside a waveguide arrangement and attached to the piston, application of a control voltage to the stator electrodes causing the reflecting member to move, thereby altering a path length of a propagating signal. Preferably the waveguide arrangement comprises first and second parallel waveguides, the waveguide cavities communicating with each other over at least a part of their common length, the first waveguide containing a radiating element for producing radiation to be propagated along the first waveguide toward the reflecting member and the second waveguide having a radiating aperture, wherein, in use, radiation propagating in the first waveguide is reflected from the reflecting member into the second waveguide and out through the radiating aperture.

In an alternative embodiment the phase-altering means comprises a waveguide having one or more dielectric slabs of a first dielectric constant fixed to the waveguide and a movable dielectric slab of a second dielectric constant disposed in co-operating relationship with the one or more fixed slabs, the movable slab being connected to the piston. The one or more fixed slabs can be fixed to an inside surface of the waveguide and define a laterally substantially central cavity free from dielectric material, the movable slab being arranged to move axially within this central cavity. The waveguide is preferably attached to one end of the stator and movable slab to the piston by means of a push-rod. There is preferably a launcher provided in the waveguide wall at a location not occupied by the fixed or movable slabs, the launcher serving to generate a wave which passes through the slabs and out through a radiating aperture in the waveguide.

The piston can be hollow and the waveguide disposed in the piston. In this case the movable slab may be connected to the piston through connecting arms projecting radially inwardly from the piston and locating inside axially oriented slots provided in the waveguide wall and in one or more of the fixed dielectric slabs.

The first dielectric constant is preferably approximately equal to the second dielectric constant.

In yet a further embodiment the phase-altering means comprises a dielectric gel contained within a waveguide. Preferably the dielectric gel is contained within a bag, an outer surface of which is attached to an inner surface of a wall of the waveguide, and a transversely central end-portion of which is connected to the piston. The piston may be attached to the bag by way of a movable dielectric slab. Preferably the gel and slab have approximately the same dielectric constant.

According to a second aspect of the invention, there is provided a steerable phased array antenna comprising an input to supply a signal to the array, a splitter to split the signal into a plurality of sub-signals and a plurality of antenna elements to transmit the sub-signals, the antenna elements having associated phase-shifting means to phase-shift the sub-signals so that the array transmits the signal steered in a chosen direction, characterised in that each of the phase-shifting means comprises a phase-shifter in accordance with the first aspect of the invention.

In like manner, in a third aspect the steerable phased array antenna is configured as a

receiving array and comprises a plurality of receiving antenna elements having associated phase-shifting means to phase-shift the signals supplied by the antenna elements and a combiner connected to the phase-shifting means to combine the phase-shifted signals, characterised in that each of the phase-shifting means comprises a phase-shifter in accordance with the first aspect of the invention.

According to a fourth aspect of the invention, there is provided a tracking system incorporating a phased array antenna according to the second aspect of the invention.

Preferably the array transmits microwave radiation. Most preferably it transmits radiation in the Ka band.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figures 1(a) and 1(b) show a schematic illustration of a phased array antenna system in accordance with the invention in a transmit mode and a receive mode, respectively;

Figure 2 shows an actuator as employed in a phase-shifting arrangement in accordance with the invention;

Figure 3 shows various shapes adopted by a component part of the actuator;

Figure 4 illustrates a first embodiment of a phase-shifter according to the invention in

two orthogonal views thereof;

Figures 5 and 6 are two orthogonal views of a second embodiment of a phase-shifter according to the invention in a first realisation thereof;

Figure 7 illustrates a second realisation of the second embodiment of a phase-shifter according to the invention in a general view;

Figure 8 is a cutaway view of the second realisation according to Figure 7;

Figure 9 is a cutaway view of the second realisation according to Figure 7 orthogonal to the view of Figure 8;

Figure 10 is the same view as Figure 9 but illustrating the displacement mechanism for the movable dielectric slab;

Figure 11 is a cutaway end-view of the second realisation according to Figure 7, and

Figure 12 shows a third embodiment of a phase-shifter according to the invention.

Figures 1a and 1b show a phased array antenna system in accordance with the invention, which is capable of full duplex operation. In Figure 1(a) a signal-processing unit 10 generates a normally sinusoidal signal of a given frequency which is amplified to a suitable level in a power amplifier 11, split as mentioned earlier in a splitter/combiner

12 into n sub-signals 13, these sub-signals 13 then being fed to respective phase-shifters 14 and thence to radiating elements 15.

In receive mode, the configuration is similar, except that individual low-noise amplifiers 16 are preferably provided for each sub-signal appearing at the output of the phase-shifters 14, rather than a single common amplifier at the combiner output 17. The apparatus 12 which operated in transmit mode as a splitter now operates in receive mode as a combiner.

This arrangement is used to transmit microwave radiation having a frequency of, typically, 30 GHz and thus a wavelength of 10 mm. In the following description the dimensions and parameters which are given relate to such a frequency, though it will be appreciated by those skilled in the art that the invention is not limited to this frequency of operation.

Figure 2 shows an actuator arrangement 20 comprising a tube 22, a bearing 24 and a piston 26. It can be seen that both the tube and the piston are elongate and so have an axial direction which is parallel to their central axes and a radial direction perpendicular to the axial direction.

The tube 22 comprises a single piece of piezoelectric ceramic material. The wall 28 of the tube has a slot 30 extending completely through its thickness which describes a helical path about the tube from one end to the other. Since piezoelectric ceramic material is hard, the tube 22 is most conveniently provided with the slot 30 while in its

green state before being fired. A suitable piezoelectric ceramic material is lead zirconate titanate (PZT).

The bearing is a resiliently deformable material, e.g. an elastomer, which may, in one realisation, have the shape of a toroid. If it is in the form of an O-ring having a circular cross-section, its thickness (in the radial direction) is arranged to be greater than the gap 32 between the piston and the tube. As a consequence, the bearing is stretched in the axial direction and squashed in the radial direction and in cross-section adopts a shape having two straight parallel sides and semi-circular ends, referred to as a "track" shape. The bearing is in contact with both the piston 24 and the internal surface of the tube and part of its effect is to centre the piston in the tube.

Instead of a toroid, the bearing may be substantially "track-shaped" to begin with and may also be hollow, the internal space being filled with a resiliently deformable material, e.g. a gas under pressure or a light oil.

The piston can comprise any material which is stiff in at least the radial direction and, if it is required to transmit displacement in an axial direction, as in most embodiments of the phase-shifter according to the present invention, it should be stiff in that direction also. It can even be hollow, which enables a piston to be provided having very low inertia. An example of a suitable low-mass material is expanded foam plastic.

The tube 22 is provided with electrodes 23, 25 on its external and internal curved surfaces, respectively, so that an electric field can be applied through the thickness of

the wall 28, thereby orientating dipoles in the material in a radial direction (that is, generally perpendicularly to the internal and external surfaces of the tube). In the configuration shown, both coatings are composed of a resistive material and contact rings 27, 29 and 31, 33 are made to bear against the ends of the outer and inner coatings, respectively. Rings 27 and 33 are connected together and likewise rings 29 and 31 and the resulting two connections form input terminals driven by a suitable power supply (not shown). The effect of this is to create voltage gradients along the axial length of the actuator tube, inside and outside the tube wall 28, the respective gradients being in opposite directions.

A similar effect can be created by employing low-resistance coatings, composed of, e.g., a metal such as silver or gold or a conducting PZT, splitting the helix halfway along its length and driving the now highly conductive coatings in antiphase by a suitable interconnection of end-connections of the coatings.

The application of the operating electric field in the manner described causes the shape of the tube to change from having a constant diameter along its length to having a flared or tapering shape extending from a relatively narrow end to a relatively wide end. This is due to the differently directed voltage gradients mentioned earlier. If an operating electric field having an opposite polarity is applied, the taper of the tube changes so that the end which was narrow becomes wide and vice-versa. Thus, switching an electric field from (a) a certain magnitude and polarity to (b) zero magnitude and thence to (c) an equal magnitude and opposite polarity to that in (a) will produce the shapes shown in Figures 3(a), 3(b) and 3(c), respectively (shown exaggerated for clarity). The degree

of shape change depends on the magnitude of the operating electric field applied.

The tube deformation just described forces the piston up and down the tube in a manner shortly to be explained.

The degree of change of shape, and hence of movement, of the piston can be enhanced by careful choice of the structure of the wall of the tube 22. Compared to a single and integral piece of one ceramic such as PZT, greater movement for the same applied voltage can be obtained by giving the wall a multilayer structure, in which a plurality of piezoelectric layers are provided, each having their own electrodes. Alternatively, lower driving voltages can be used to produce the same movement.

Alternative enhanced wall structures include a unimorph bender, in which the ceramic tube is bonded onto or inside a metal liner, and a bimorph bender, in which the tube comprises two piezoelectric tubes bonded together one inside the other, the tubes being poled in opposite, preferably radial, directions. In both unimorph and bimorph benders the enhanced movement is due to differential expansion occurring during operation.

The use of PZT may provide, for example, a 10 mm displacement of the piston in a response time of 25 ms. This may be under an operating voltage of 150 V for a tube wall thickness of 21mm, although lower voltages could be used if a multi-layer tube was provided having thinner individual layers of piezoelectric material. Other wall structures can be used, as has already been mentioned.

As an operating electric field is applied to the tube, the internal diameter of the tube decreases at one end and increases at the other and this causes a "rolling" motion of the bearing which forces the piston toward the wider end of the tube. More precisely, points of mutual contact between the bearing and wall on the one hand and between the bearing and piston on the other do not move relative to each other except at the ends of the bearing where the bearing material rolls away from/onto its respective contact surface. Thus, in these end-regions, parts of the surface of the bearing either move into contact with the piston or move out of contact with it and a similar effect occurs between the surface of the bearing and the tube. The rolling action just described does not involve sliding friction, rather the presence of static friction prevents relative motion of the bearing and wall and of the bearing and piston.

It will be understood that, being-based on a simple mechanical arrangement, the actuators themselves are relatively inexpensive and allow a relatively inexpensive steerable phased array to be produced by means of them in accordance with the invention.

In producing a steerable phased array it is necessary for phase shifts of different values to be applied to the subsignal radiation being transmitted by the individual radiating elements in order that a beam may be steered. At most, a relative phase shift of one wavelength is required between antennas in the array. This means that, for transmitted radiation having a wavelength of 10 mm, a maximum relative wavelength shift of 10 mm is required.

The actuator arrangement 20 can induce a phase shift in transmitted radiation in a number of ways. In a first embodiment, illustrated in Figure 4, the actuator has a reflector 34 attached both to the piston 26 and to a cavity-separator extension piece 36 which extends axially of the reflector 34 and comprises a separating section 42 proper and an aperture section 44 disposed between the separating section 42 and the reflector 34. A pair of waveguide sections 38, 40 having parallel longitudinal axes are divided one from the other by, firstly, a fixed separator member 46 and, secondly, the cavity-separator separating section 42. One waveguide section 40 is provided with a radiating element 48 at its distal end and the other waveguide section 38 has a radiating aperture 50 at its distal end. The proximal ends of both waveguide sections are attached in common to the wall 28 of the actuator arrangement 20.

The mode of operation of this embodiment is as follows. A signal is radiated from the radiating element 48 and propagates down the waveguide section 40 towards the reflector 34 which reflects it through the aperture 44 in the cavity separator 36 into the adjacent waveguide section 38. When in the waveguide section 38, the signal is guided toward the radiating aperture 50. By moving the reflector by means of the PZT actuator arrangement 20, the path length between the radiating element 48 and the radiating aperture 50 is varied by an incremental amount, thereby modifying the phase of the signal leaving the radiating aperture 50. The reflector 34 and cavity separator 36 are moved linearly in the waveguide sections by the piston 36 that is moved by the squeezing action of the actuator.

In a second embodiment (see Figures 5 and 6) a single waveguide 54, which is likewise

attached to the wall 28 of the actuator 20 at one end thereof, contains two fixed dielectric slabs 56 attached to opposite inside walls of the waveguide and a movable dielectric slab 58 attached by a rod 60 to the piston 26. The dielectric constant of the movable slab is approximately the same as that of the fixed slabs. The waveguide is provided with a launcher 62 which is received through an opening 64 in a side wall of the waveguide.

In operation, a signal is radiated from the launcher into the waveguide cavity. The signal propagates along the waveguide towards the fixed and movable dielectric slabs 56, 58 which modify the wavelength of the signal in proportion to the length of the overlap between the moving and fixed dielectric slabs. More precisely, the phase-shift in the radiated signal is expressed as:

$$\Delta\phi = \{(\beta_1 + \beta_3) - (\beta_2 + \beta_4)\} \times x$$

where x = displacement of the movable slab from its fully overlapping position and βn = propagation constant as seen by the wave as it travels from the launcher outwards. Looking at Figure 5, β_1 applies between the bottommost part of the fixed slabs 56 and the bottommost part of the movable slab 58; β_2 applies between the bottommost part of the movable slab and the topmost part of the fixed slabs; β_3 applies between the topmost part of the fixed slabs and the topmost part of the movable slab, and β_4 applies beyond that.

A variation of this embodiment is illustrated in Figures 7-11. In this variant realisation the mode of operation is exactly the same, but the construction is different. Instead of the movable dielectric slab being coupled to the piston by means of a push rod 60

(Figures 5 and 6), it is directly attached to the piston through connecting arms 70. The connecting arms 70 pass through slots 71 in the waveguide 72 and fixed dielectric slabs 74 and are attached to the movable slab 76 at an intermediate point thereof along its length. Thus in this realisation the actuator surrounds part of the waveguide 72 rather than being at one end of it, as in the Figure 5/6 realisation. As in the first realisation, though, the waveguide is secured to the actuator stator.

Figures 9 and 10 are views of Figure 8 from the side, like features being designated by like reference numerals. Figure 10 shows the slot 71 in the waveguide and fixed dielectric slabs 74 and a connecting arm 70 in section which, in practice, connects the piston 73 and the movable slab 76. Either one slot only may be provided on one side of the waveguide and involving only one fixed slab, or two slots may be provided on opposite sides. The latter, balanced, arrangement is preferred for mechanical reasons. Figure 11 is a cutaway underside end-view of the second realisation of the second embodiment and shows the actuator wall 28, the bearing 24, the piston 73, the waveguide 72, the launcher 62 and, inside the waveguide, the fixed slabs 74 and movable slab 76. The slot 71 made in the waveguide wall and in the fixed slabs 74 is also shown.

In a third, alternative, embodiment shown in Figure 12 the piston 26 is used to drive, through a connecting rod 60, a movable dielectric slab 76 which is attached at its ends 82, 84 to a deformable bag 80 filled with a dielectric gel 86. The slab and gel both ideally have approximately the same dielectric constant. The bag 80 is secured on its outer face to inner, opposite wall-faces of the waveguide 54. In operation the piston

moves the rod 60, which displaces the movable dielectric slab 76, which, in turn, imposes a distortion in the shape of the bag 80. The effect is similar to that of the fixed/movable slab embodiment, wherein a change in the path length of the propagated signal associated with a particular propagation constant causes a phase-shift in that signal.

In all these embodiments and realisations the displacement of the piston needs to be in the region of one wavelength, that is about 10 mm for a 30 Ghz signal, to produce a phase-shift equal to one wavelength.

It should be noted that the helically slotted piezoelectric tube provides for large displacement in relation to its size. For an arrangement in which the bearing is located at one end of the tube and is displaceable to the other end of the tube, the maximum possible displacement of the piston is the length of the tube. Of course, if the piston is located more towards the mid-point of the tube, the displacement would be less. This latter configuration provides a convenient way of achieving a type of "centre-zero" arrangement whereby in the piston's rest position (mid-position) the phase-shifter corresponds to zero phase shift, but when the piston is driven to one side or other of its mid-position there is a positive or negative phase shift, respectively.

By creating an array of independently controllable actuators/phase-shifters to form a suitable aperture, it is possible to steer a transmitted signal in space by varying the displacement of the actuator pistons relative to each other. In an embodiment operating at 30 GHz having a hexagonal aperture of 0.5 m and a square array having an element

spacing of half a wavelength, 7700 individual antennas are required. With a microwave reflector as described in the first embodiment (Figure 4) the rate of change of phase-shift $\delta\theta/\delta t$ of each element is about 28 deg ms^{-1}. With a dielectric-filled waveguide this rate of change is influenced by the phase velocity of the radiation within the dielectric medium, as well as by the velocity of the dielectric piston. Assuming that the actuators can induce a relative phase shift of up to 360° between particular antennas, the array can track at least ±45° from boresight.

In order to ensure that grating lobes are not generated in "visible" space, the lateral spacing of the radiating elements in the array should be approximately half a wavelength, i.e. about 5 mm for radiation having a frequency of 30 GHz..

A significant benefit of the invention is that it enables phase shifting to be incorporated into the antenna. Indeed, it may be conveniently arranged for the end of the waveguide through which the radiation is exiting to constitute the radiating antenna itself, so that no additional discrete antenna element is required. Thus in this realisation the radiating aperture may be considered to constitute the actual antenna element. Alternatively, the waveguide may be coupled to its own discrete antenna element (not shown). The result is a low-cost phased array system compared with conventional systems which traditionally use large quantities of expensive active microwave components or a likewise costly complex mechanical arrangement. By incorporating phase-shifting into the antenna, a whole array can be fed directly from a single manifold, as illustrated in Figures 1(a) and 1(b) (see splitter/combiner 12). Furthermore, since the various phase-shifters described are able to withstand large amounts of RF power without damage, the

manifold may be preceded by just a single high power microwave amplifier 11.

Although the array has a relatively fast response time, it is not as fast as pure solid state electronically scanned arrays. Nevertheless, the scanning rate of these arrays is certainly fast enough to be used as an antenna arrangement in satellite tracking. It is also fast enough to be used in numerous communications applications where switching of a transmitting or receiving direction is required, such as OTM (on the move) Communications for HMMWV (high-mobility multi-wheeled vehicle) and UAV (unmanned airborne vehicles).

CLAIMS

1. A phase-shifter comprising: phase-altering means for introducing a phase shift into a signal whose phase is to be controlled and an actuator (20)which changes shape in response to an electrical control signal, wherein the actuator is mechanically connected to the phase-altering means such that the change in shape of the former leads to a phase-altering action in the latter; characterised in that the actuator comprises a tubular stator (22) of piezoelectric or magnetostrictive material; a piston (26) coaxially disposed within the stator and a bearing member (24) disposed between the stator (22) and piston (26), wherein the stator (22) distorts in an approximately frustro-conical manner in response to said control signal thereby causing the bearing member (24) to roll axially along the stator(22), the movement of the bearing member (24) in turn causing axial movement of the piston (26).

2. A phase-shifter according to Claim 1 in which the stator comprises a piezoelectric tubular member (22) having an electrode structure (23, 25) on its internal and external curved surfaces for coupling to a source of the control voltage and the bearing member (24) is an elastically deformable member of approximately annular cross-section.

3. A phase-shifter according to Claim 1 or Claim 2 in which the stator has a slot (30) extending completely through the wall (28) of the tubular member (22) and which describes a helical path about the tubular member (22).

4. A phase-shifter according to any preceding claim in which the phase-altering means comprises a reflecting member (34) attached to the piston (26), the reflecting member (34) being disposed inside a waveguide arrangement (38, 40), whereby application of a control voltage to the actuator (20) causes the reflecting member (34) to move inside the waveguide arrangement (38,40), thereby altering a path length of a signal propagated along the waveguide arrangement.

5. A phase-shifter according to Claim 4 in which the waveguide arrangement comprises first (40) and second (38) parallel waveguides, the waveguide cavities communicating (44) with each other over at least a part of their common length, the first waveguide (40) containing a radiating element (48) for producing radiation to be propagated along the first waveguide (40) toward the reflecting member and the second waveguide having a radiating aperture (50), wherein, in use, radiation propagating in the first waveguide (40) is reflected from the reflecting member (34) into the second waveguide (38) and out through the radiating aperture (50).

6. A phase-shifter according to any one of Claim 1 to 3 in which the phase-altering means comprises a waveguide (54; 72) containing one or more dielectric slabs (56; 74) made of a material of a first dielectric constant fixed to the waveguide and a movable dielectric slab (58; 76) made of a material of a second dielectric constant disposed in co-operating relationship with the one or more fixed slabs (56; 74), the movable slab (58; 76) being connected to the piston (26; 73).

7. A phase-shifter according to Claim 6 in which the one or more fixed slabs (56) are secured to an inside surface of the waveguide wall and define a laterally substantially central cavity free from dielectric material, and wherein the movable slab (58) is arranged to be axially movable within said substantially central cavity.

8. A phase-shifter according to Claim 7 in which the waveguide (54) is attached to one end of the actuator stator (22) and the movable dielectric slab (58) is connected to the piston (26) by means of a push rod (60).

9. A phase-shifter according to Claim 7 in which the piston (73) is hollow and the waveguide (72) is disposed in the piston.

10. A phase-shifter according to Claim 9 in which the movable dielectric slab (76) is connected to the piston (73) by means of connecting arms (70) projecting radially inwardly from the piston (73) and locating inside axially oriented slots (71) provided in the waveguide (72) wall and in one or more of the fixed dielectric slabs (74).

11. A phase-shifter according to any one of Claims 6 to 10 and further comprising a launcher (62) is provided in the waveguide wall at a location not occupied by the fixed (56; 74) or movable (58; 76) dielectric slabs, the launcher (62) serving to generate a wave which passes through the slabs and out through a radiating aperture of the waveguide.

12. A phase-shifter according to any one of Claims 6 to 11 in which said first dielectric constant is approximately the same as said second dielectric constant.

13. A phase-shifter according to any one of Claims 1 to 3 in which the phase-altering means comprises a dielectric gel (86) contained within a waveguide (54).

14. A phase-shifter according to Claim 13 in which the dielectric gel (86) is contained within a bag (80), an outer surface of which is attached to an inner surface of a wall of the waveguide (54), and a transversely central end-portion of which is connected to the piston (26).

15. A phase-shifter according to Claim 14 in which the piston (26) is attached to the bag (80) by way of a movable dielectric slab (76).

16. A phase-shifter according to Claim 15 in which the movable slab (76) and the gel (86) have approximately the same dielectric constant.

17. A steerable phased array antenna, comprising an input to supply a signal to the array, a splitter (12) to split the signal into a plurality of sub-signals (13) and a plurality of antenna elements (15) to transmit the sub-signals, the antenna elements (15) having associated phase-shifting means (14) to phase-shift the sub-signals (13) so that the array transmits the signal steered in a chosen direction; characterised in that each of the phase-shifting means (14) comprises

a phase-shifter according to any preceding claim.

18. A steerable phased array antenna according to Claim 17 and further comprising a power amplifier (11) connected between the input supplying the signal to the array and the splitter (12).

19. A steerable phased array antenna comprising a plurality of receiving antenna elements (15) having associated phase-shifting means (14) to phase-shift the signals supplied by the antenna elements(15) and a combiner (12) connected to the phase-shifting means (14) to combine the phase-shifted signals, characterised in that the phase-shifting means (14) comprises a phase-shifter according to any one of Claims 1 to 16.

20. A steerable phased array antenna according to Claim 19 and further comprising a plurality of amplifiers (16) connected between respective phase-shifting means (14) and the combiner (12).

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
P/61695/PC		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 02188	07/06/2000	19/06/1999
Applicant		
MARCONI CASWELL LIMITED		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [ ] the text is approved as submitted by the applicant.

   [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from th date of mailing of this international search report, submit comments to this Authority.

6. Th figure of the **drawing** to be published with th abstract is Figure No. 4

   [X] as suggested by th applicant.

   [ ] because th applicant failed to suggest a figur .

   [ ] because this figur better charact riz s th invention.

   [ ] None of the figures.

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

TOLFREE R. K.
MARCONI Int.Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
GRANDE BRETAGNE

FOREIGN PC RKT Rule 26 MAR 2001

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	26.03.01
Applicant's or agent's file reference P/61695/PC	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02188	07/06/2000	19/06/1999

Applicant
MARCONI CASWELL LIMITED

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Kellerer, C Tel.+49 89 2399-2261

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P/61695/PC		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02188	07/06/2000	19/06/1999
International Patent Classification (IPC) or national classification and IPC H01P1/18		
Applicant MARCONI CASWELL LIMITED		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 10 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
16/01/2001	26.03.01
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Van der Peet, H Telephone No. +49 89 2399 2764

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02188

I. Basis of the r port

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
Description, pages:

1-17	as originally filed

Claims, No.:

1-20	as originally filed

Drawings, sheets:

1/10-10/10	as received on	09/08/2000	with letter of	03/08/2000

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-20
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations
see separate sheet

1. Document US-A-4710733 (hereinafter: document D2) discloses in figure 2 a phase-shifter comprising: phase altering-means (6) for introducing a phase shift into a signal (15) whose phase is to be controlled and an actuator (12B) which changes shape in response to an electrical control signal (8B), wherein the actuator is mechanically connected to the phase-altering means (6) such that the change in the shape of the former leads a phase-altering action in the latter. The features of the characterising portion of claims 1 and 17 are neither known from document D2 nor from patent document US-A-5504466 (hereinafter: document D1). The subject matter of claim 1 and of claim 17 is accordingly novel and cannot be rendered obvious by the technical teaching of documents D1 and D2.

Fig.1(a).

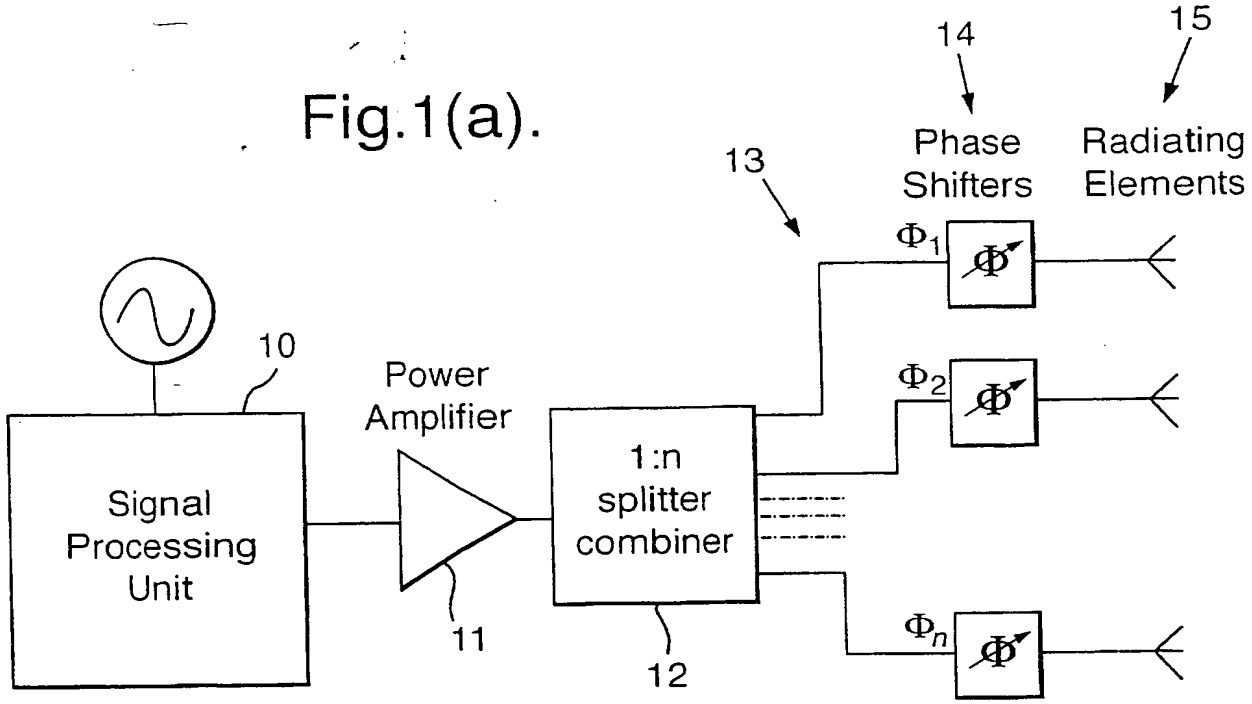

14
15
Phase Shifters
Radiating Elements
13
Φ_1
Φ_2
Φ_n
10
Power Amplifier
Signal Processing Unit
1:n splitter combiner
11
12

Fig.1(b).

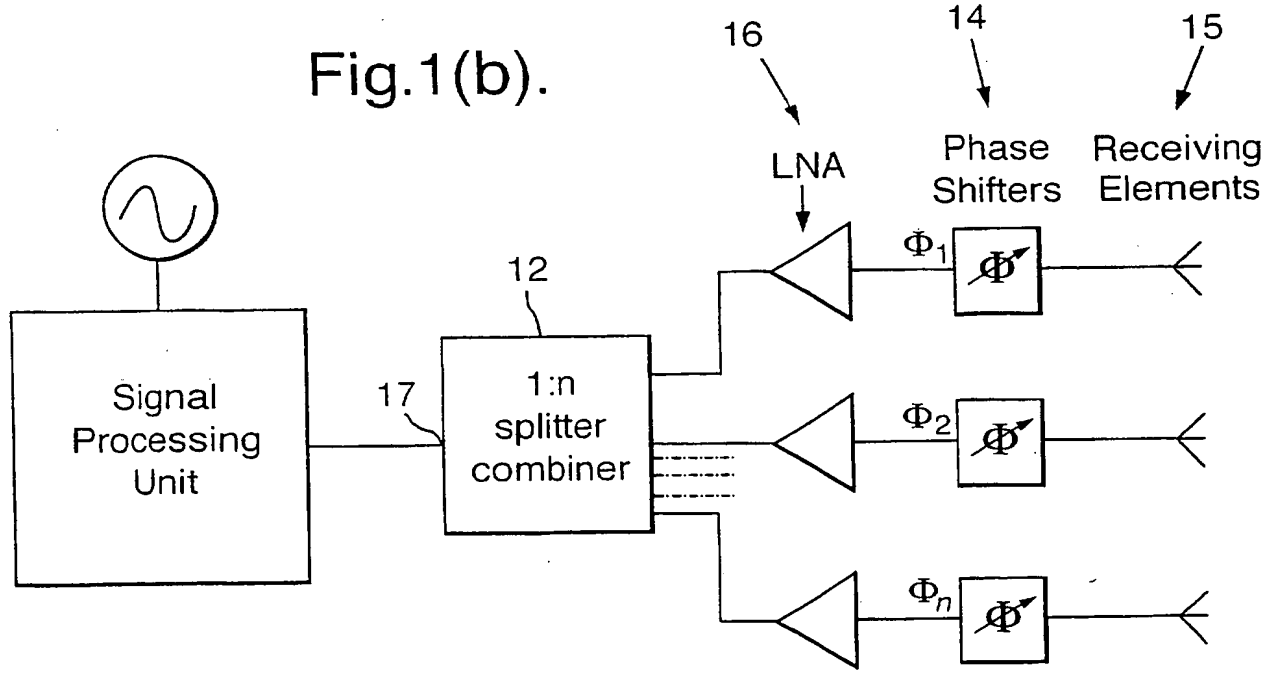

16
14
15
LNA
Phase Shifters
Receiving Elements
Φ_1
Φ_2
Φ_n
12
17
Signal Processing Unit
1:n splitter combiner

Fig.2.

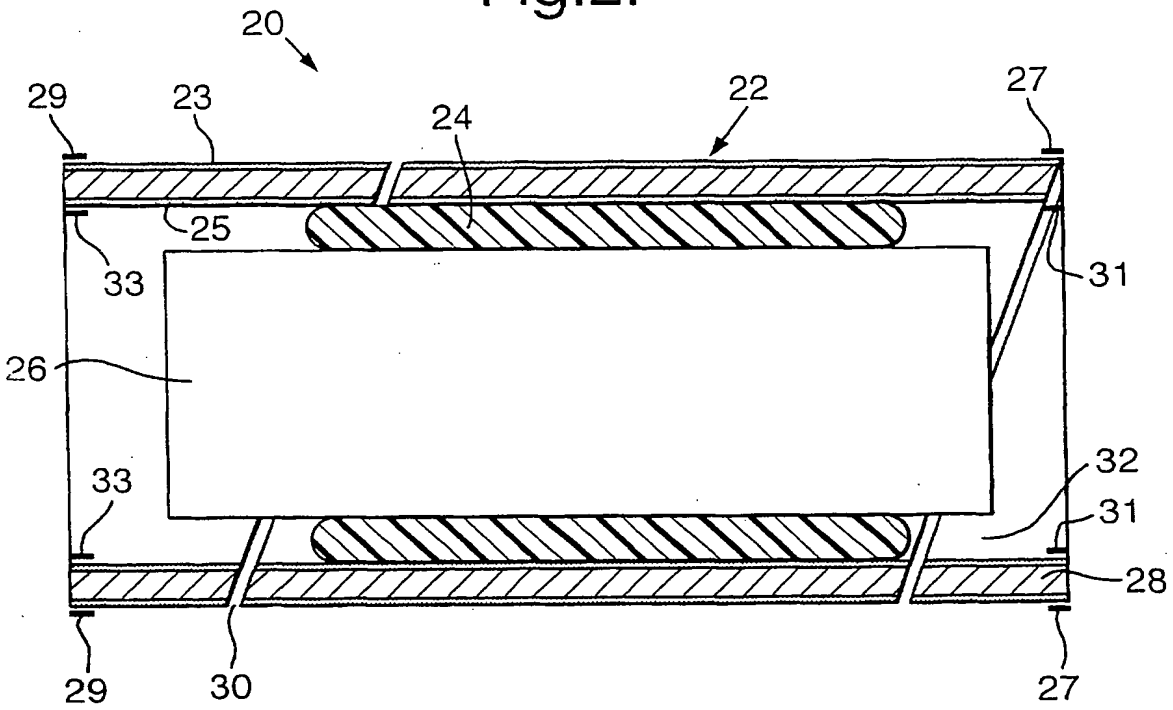


Fig.3(a).

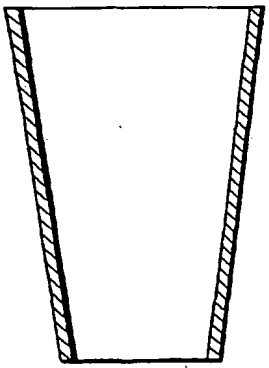


Fig.3(b).

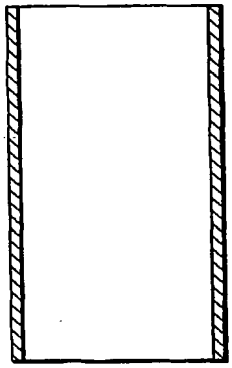


Fig.3(c).

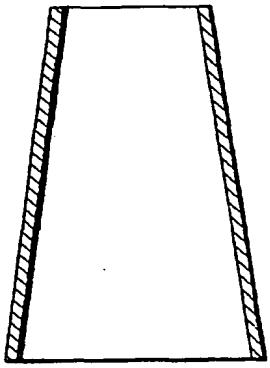
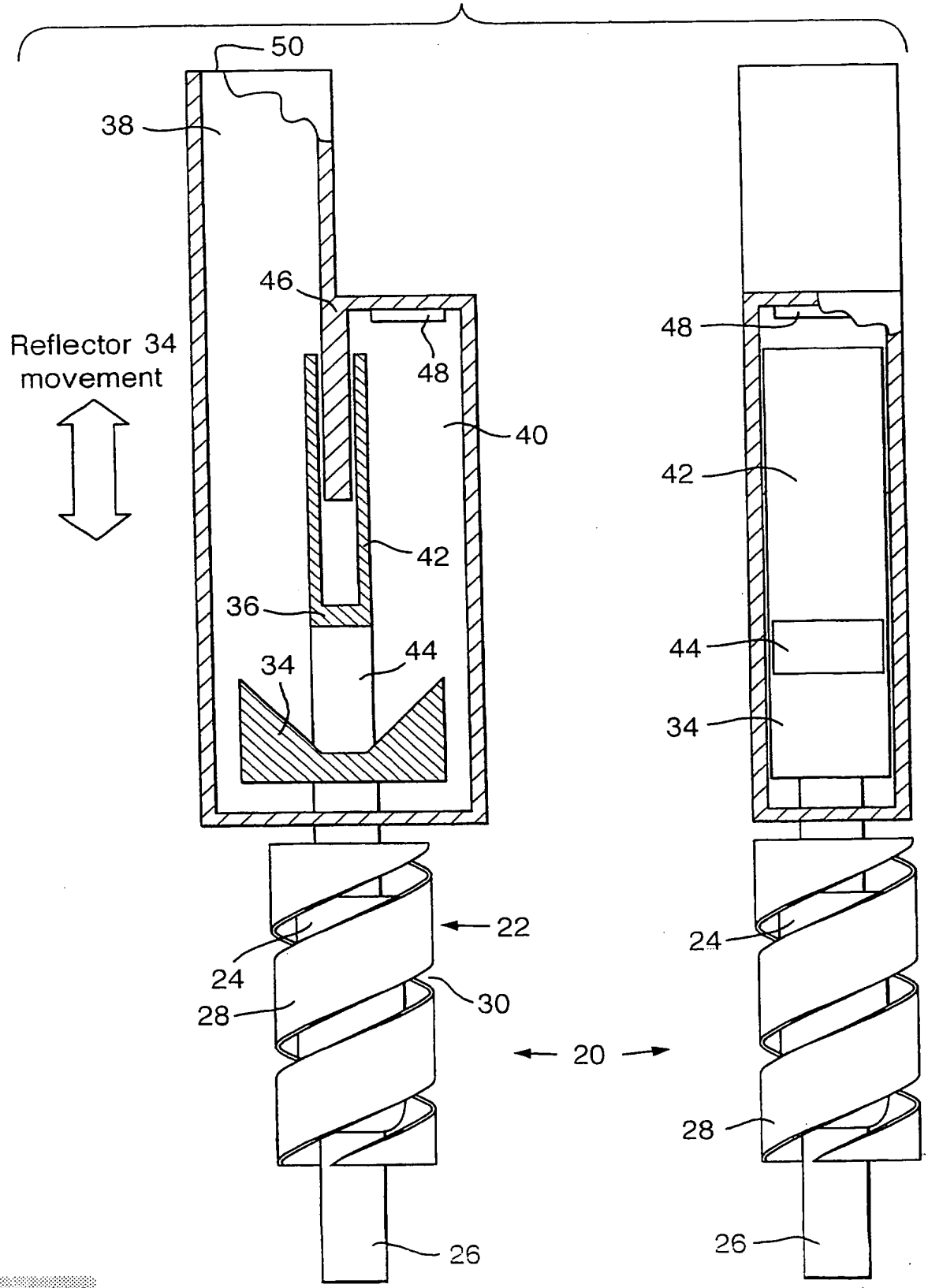


Fig.4.


50
38
46
48
Reflector 34 movement
40
42
36
44
34
22
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28
30
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42
44
34
24
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26
26

Fig.5.

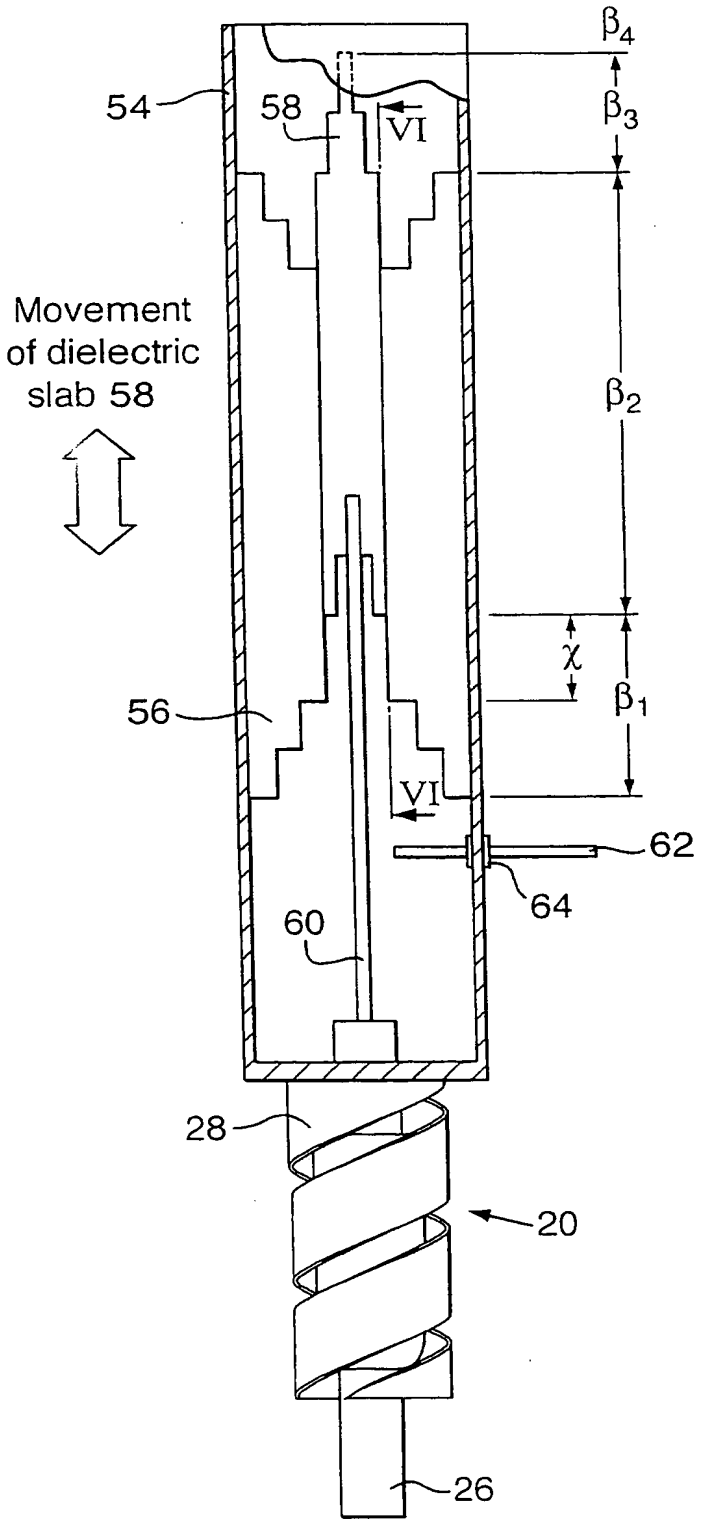

β_4
β_3
β_2
β_1
χ
54
58
VI
56
VI
62
64
60
28
20
26
Movement of dielectric slab 58

Fig.6.

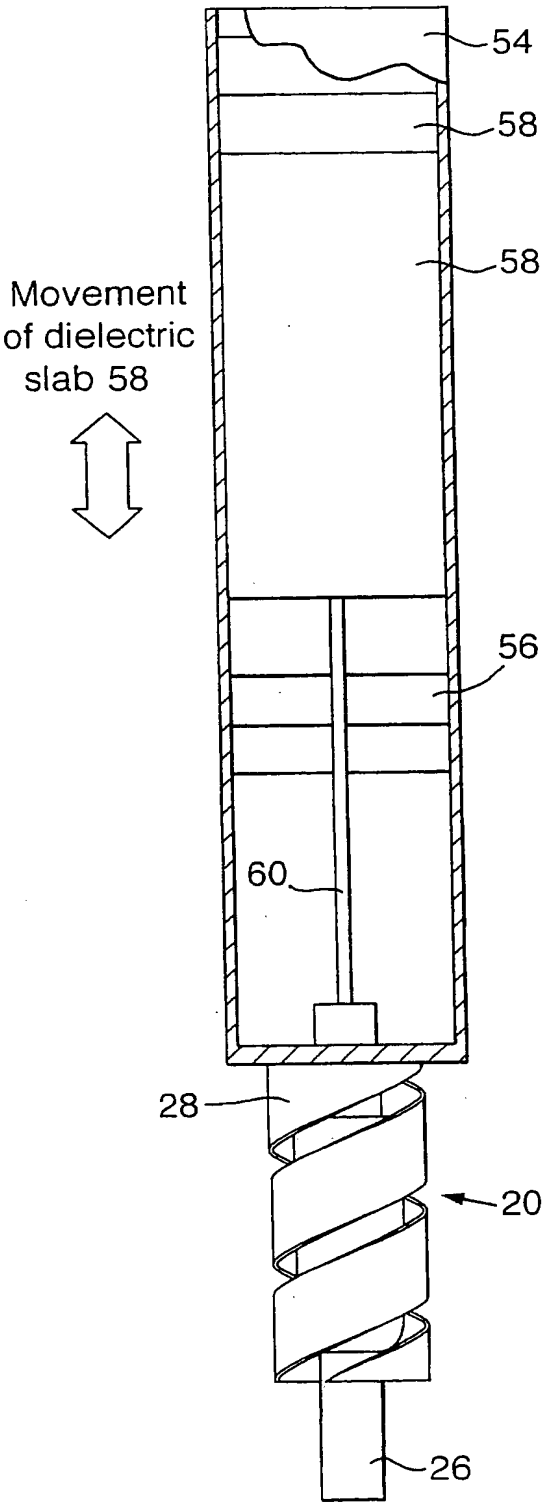

54
58
58
56
60
28
20
26
Movement of dielectric slab 58

Fig.7.

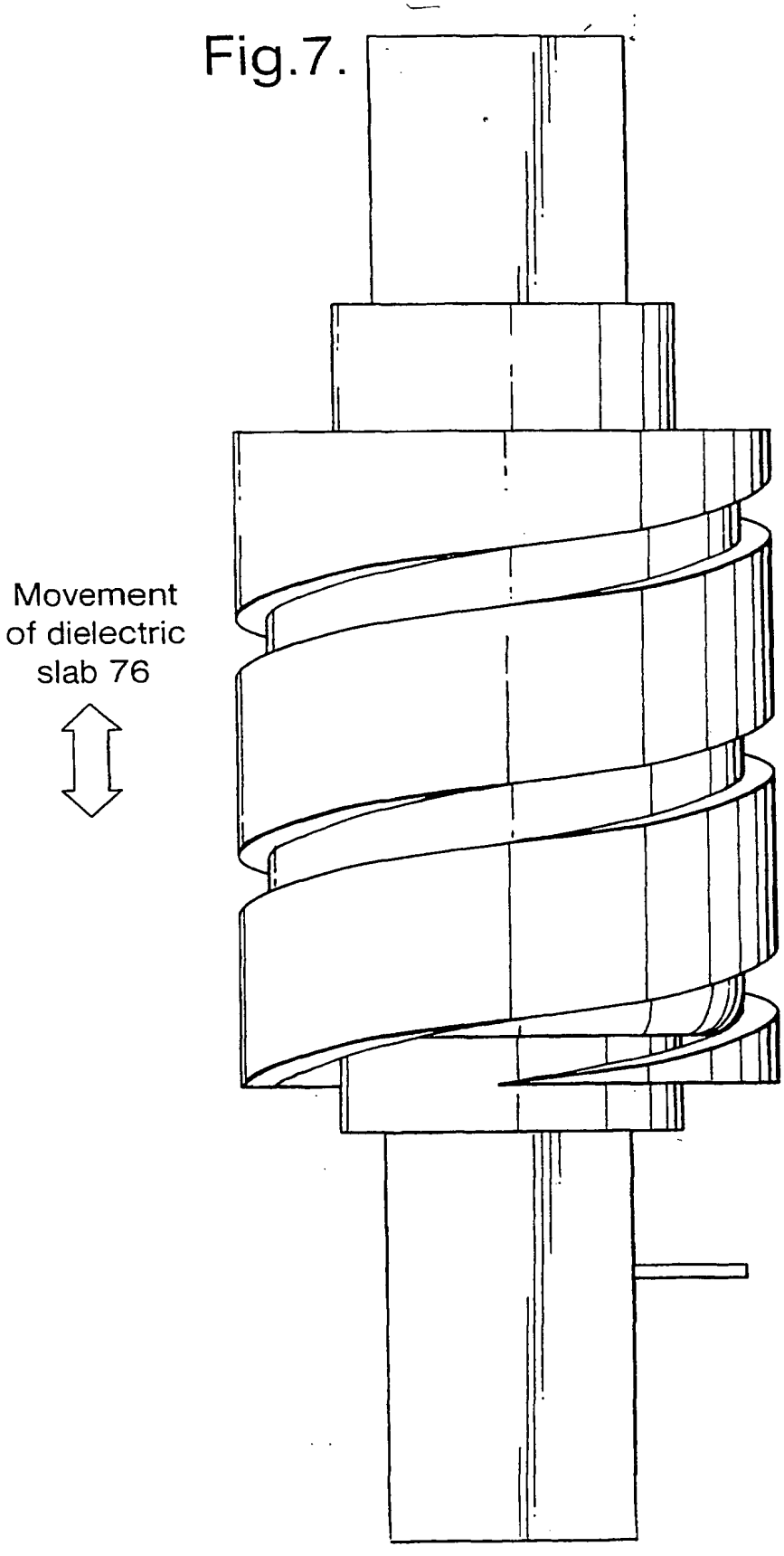


Fig.8.

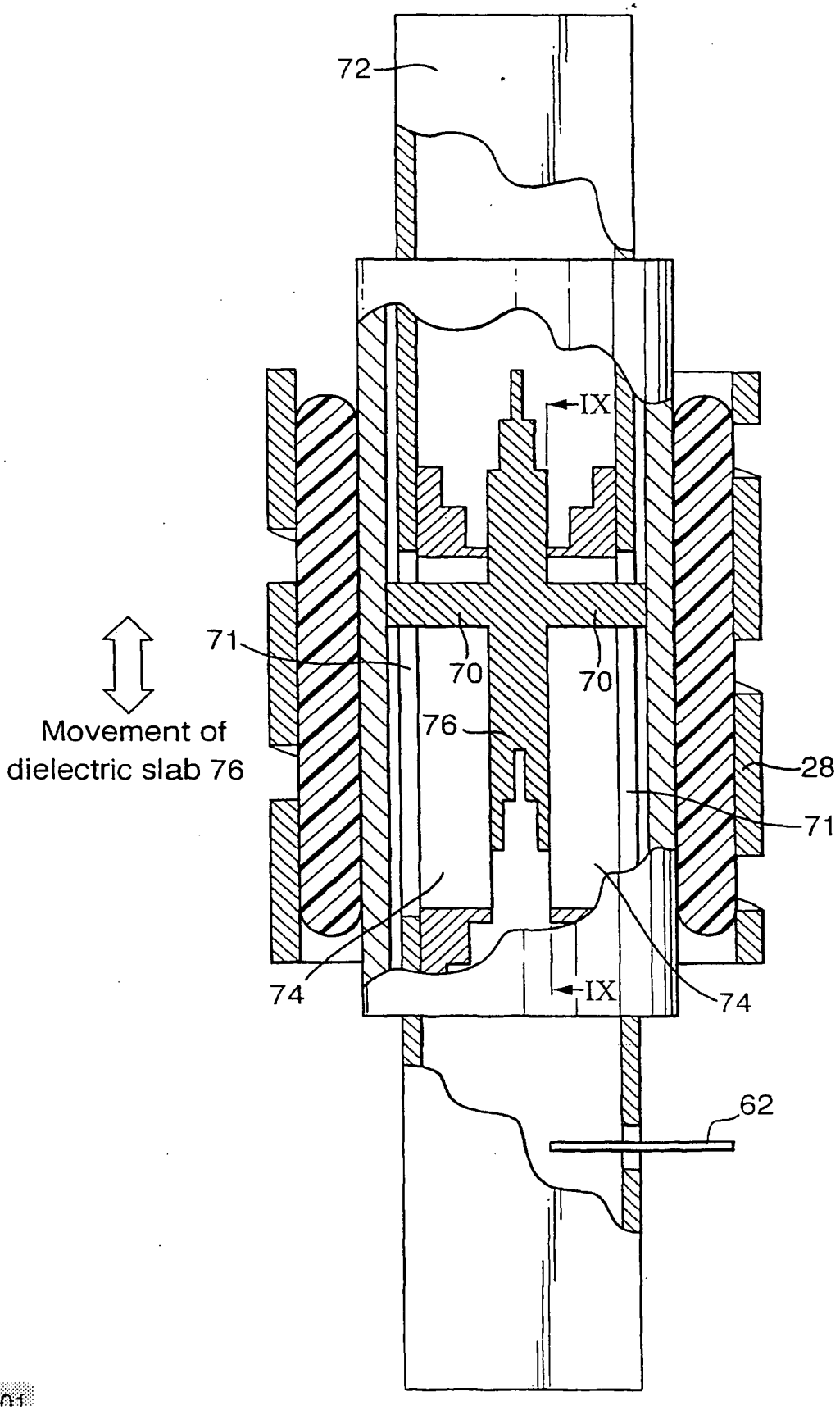

72
IX
71
70
70
76
28
71
74
IX
74
62
Movement of dielectric slab 76

Fig.9.

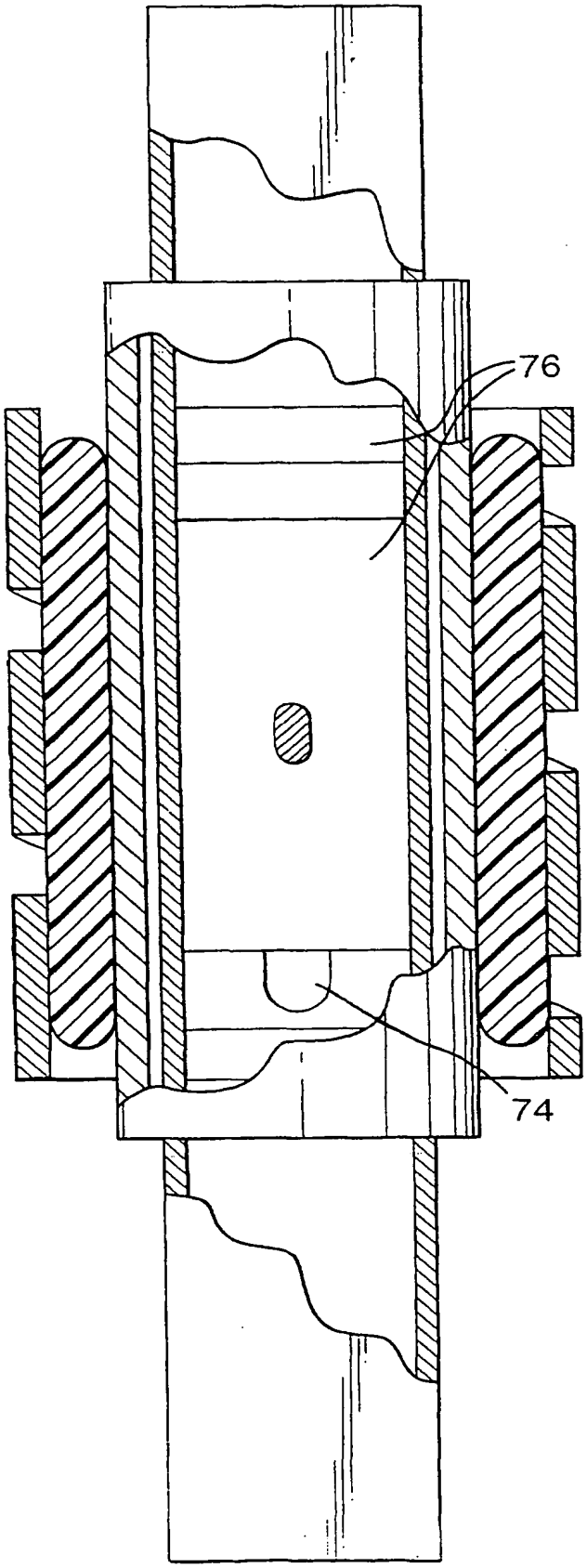


Fig.10.

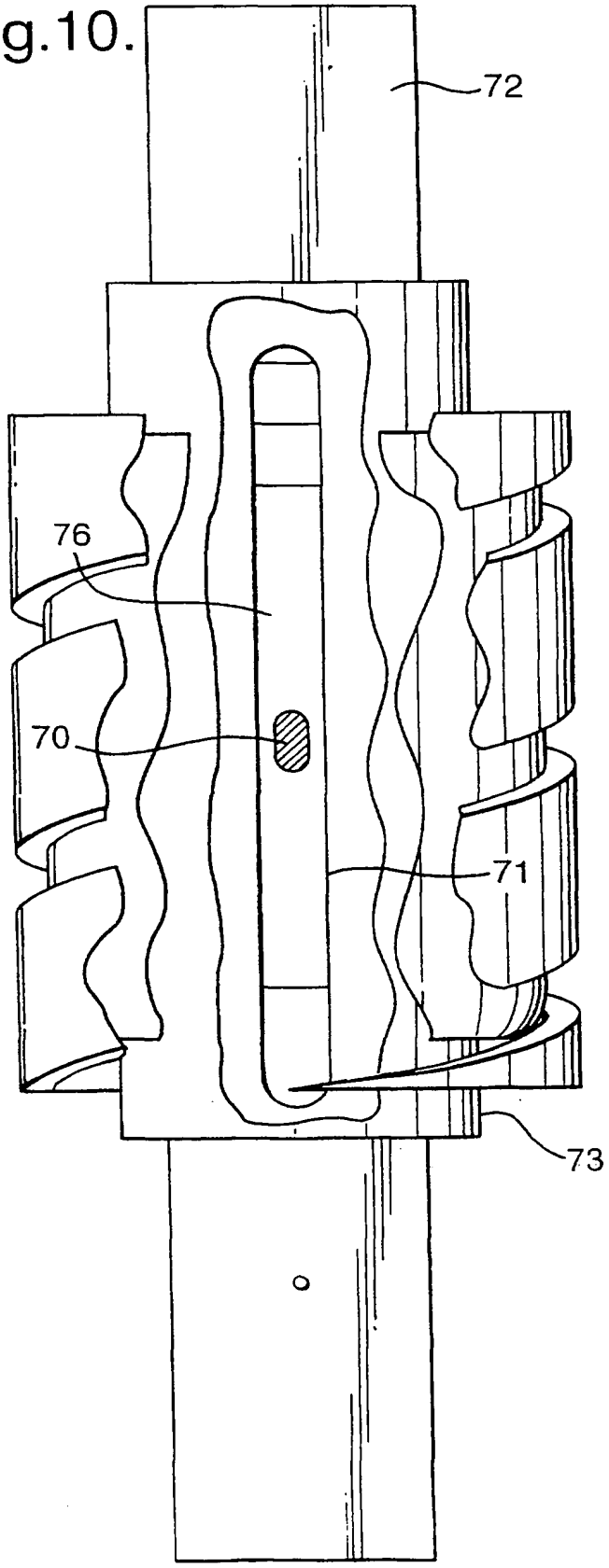


Fig.11.

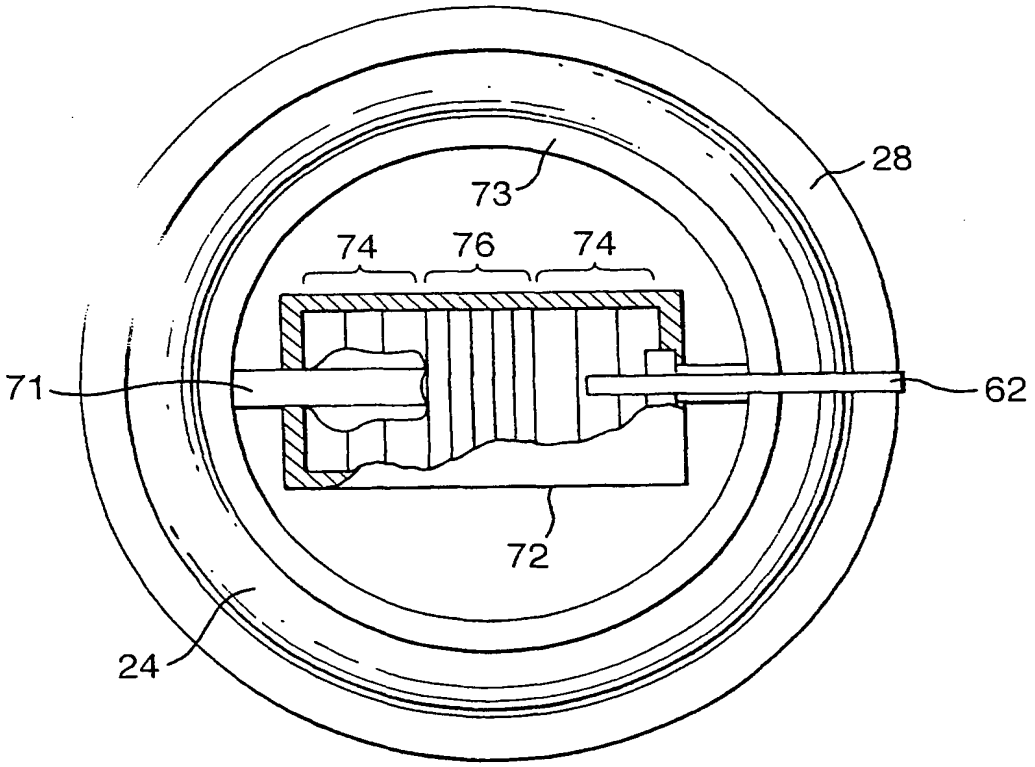
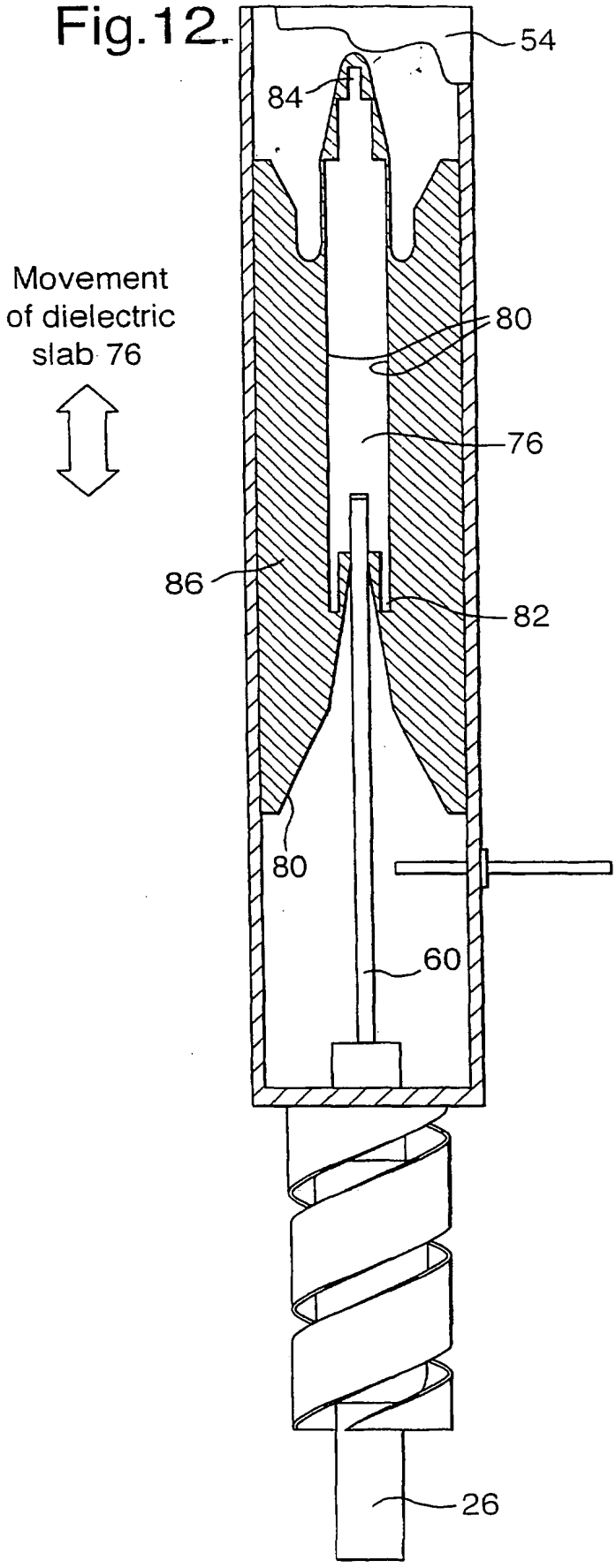


Fig.12.



PATENT COOPERATION TREAT

From the INTERNATIONAL BUREAU

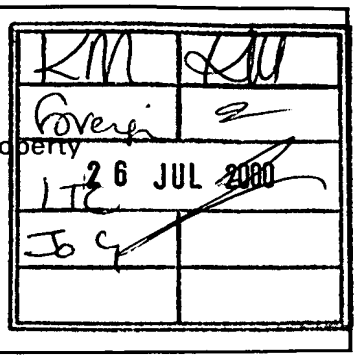
PCT

NOTIFICATION OF RECEIPT OF RECORD COPY

(PCT Rule 24.2(a))

To:

HOSTE, Colin, Francis
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI



Date of mailing (day/month/year)	IMPORTANT NOTIFICATION
14 July 2000 (14.07.00)	
Applicant's or agent's file reference	**International application No.**
P/61695/PC	PCT/GB00/02188

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

MARCONI CASWELL LIMITED (for all designated States except US)
LANE, Anthony, Alan et al (for US)

International filing date	:	07 June 2000 (07.06.00)
Priority date(s) claimed	:	19 June 1999 (19.06.99)
Date of receipt of the record copy by the International Bureau	:	28 June 2000 (28.06.00)
List of designated Offices	:	

AP :GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW
EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
National :AE,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,CA,CH,CN,CR,CU,CZ,DE,DK,DM,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,NO,NZ,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,US,UZ,VN,YU,ZA,ZW

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- [X] time limits for entry into the national phase
- [X] confirmation of precautionary designations
- [X] requirements regarding priority documents

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer:

Anman QIU

Telephone No. (41-22) 338.83.38

INFORMATION ON TIME LIMITS FOR ENTERING THE NATIONAL PHASE

The applicant is reminded that the "national phase" must be entered before each of the designated Offices indicated in the Notification of Receipt of Record Copy (Form PCT/IB/301) by paying national fees and furnishing translations, as prescribed by the applicable national laws.

The time limit for performing these procedural acts is **20 MONTHS** from the priority date or, for those designated States which the applicant elects in a demand for international preliminary examination or in a later election, **30 MONTHS** from the priority date, provided that the election is made before the expiration of 19 months from the priority date. Some designated (or elected) Offices have fixed time limits which expire even later than 20 or 30 months from the priority date. In other Offices an extension of time or grace period, in some cases upon payment of an additional fee, is available.

In addition to these procedural acts, the applicant may also have to comply with other special requirements applicable in certain Offices. **It is the applicant's responsibility** to ensure that the necessary steps to enter the national phase are taken in a timely fashion. Most designated Offices do not issue reminders to applicants in connection with the entry into the national phase.

For detailed information about the procedural acts to be performed to enter the national phase before each designated Office, the applicable time limits and possible extensions of time or grace periods, and any other requirements, see the relevant Chapters of Volume II of the PCT Applicant's Guide. Information about the requirements for filing a demand for international preliminary examination is set out in Chapter IX of Volume I of the PCT Applicant's Guide.

GR and ES became bound by PCT Chapter II on 7 September 1996 and 6 September 1997, respectively, and may, therefore, be elected in a demand or a later election filed on or after 7 September 1996 and 6 September 1997, respectively, regardless of the filing date of the international application. (See second paragraph above.)

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

CONFIRMATION OF PRECAUTIONARY DESIGNATIONS

This notification lists only specific designations made under Rule 4.9(a) in the request. It is important to check that these designations are correct. Errors in designations can be corrected where precautionary designations have been made under Rule 4.9(b). The applicant is hereby reminded that any precautionary designations may be confirmed according to Rule 4.9(c) before the expiration of 15 months from the priority date. If it is not confirmed, it will automatically be regarded as withdrawn by the applicant. There will be no reminder and no invitation. Confirmation of a designation consists of the filing of a notice specifying the designated State concerned (with an indication of the kind of protection or treatment desired) and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.

REQUIREMENTS REGARDING PRIORITY DOCUMENTS

For applicants who have not yet complied with the requirements regarding priority documents, the following is recalled.

Where the priority of an earlier national, regional or international application is claimed, the applicant must submit a copy of the said earlier application, certified by the authority with which it was filed ("the priority document") to the receiving Office (which will transmit it to the International Bureau) or directly to the International Bureau, before the expiration of 16 months from the priority date, provided that any such priority document may still be submitted to the International Bureau before that date of international publication of the international application, in which case that document will be considered to have been received by the International Bureau on the last day of the 16-month time limit (Rule 17.1(a)).

Where the priority document is issued by the receiving Office, the applicant may, instead of submitting the priority document, request the receiving Office to prepare and transmit the priority document to the International Bureau. Such request must be made before the expiration of the 16-month time limit and may be subjected by the receiving Office to the payment of a fee (Rule 17.1(b)).

If the priority document concerned is not submitted to the International Bureau or if the request to the receiving Office to prepare and transmit the priority document has not been made (and the corresponding fee, if any, paid) within the applicable time limit indicated under the preceding paragraphs, any designated State may disregard the priority claim, provided that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity to furnish the priority document within a time limit which is reasonable under the circumstances.

Where several priorities are claimed, the priority date to be considered for the purposes of computing the 16-month time limit is the filing date of the earliest application whose priority is claimed.

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

HOSTE, Colin, Francis
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI

FOREIGNS - PC
FWC
23 OCT 2000

Date of mailing (day/month/year) 16 October 2000 (16.10.00)	
Applicant's or agent's file reference P/61695/PC — FILE WP CWP PLS	**IMPORTANT NOTIFICATION**
International application No. PCT/GB00/02188	International filing date (day/month/year) 07 June 2000 (07.06.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 19 June 1999 (19.06.99)
Applicant MARCONI CASWELL LIMITED et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
19 June 1999 (19.06.99)	9914280.4	GB	04 Sept 2000 (04.09.00)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

Magda BOUACHA

Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

TOLFREE, Roger, Keith
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI

Date of mailing (day/month/year)
26 February 2001 (26.02.01)

Applicant's or agent's file reference
P/61695.WOP/

IMPORTANT NOTIFICATION

International application No.
PCT/GB00/02188

International filing date (day/month/year)
07 June 2000 (07.06.00)

1. The following indications appeared on record concerning:

[ ] the applicant [ ] the inventor [X] the agent [ ] the common representative

Name and Address
HOSTE, Colin, Francis
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
United Kingdom

State of Nationality:
State of Residence:
Telephone No.: +44 (0) 1245 275454
Facsimile No.: +44 (0) 1245 275114
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[X] the person [ ] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address
TOLFREE, Roger, Keith
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
United Kingdom

State of Nationality:
State of Residence:
Telephone No.: +44 (0) 1245 275563
Facsimile No.: +44 (0) 1245 275469
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[X] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer
R. Chrem
Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREAT

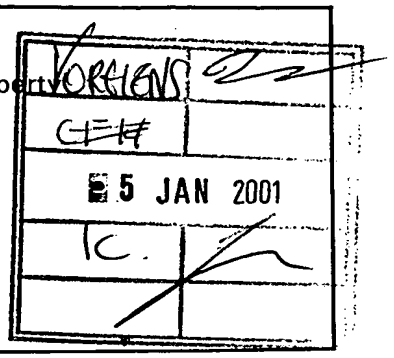
From the INTERNATIONAL BUREAU

PCT

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:
HOSTE, Colin, Francis
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI



Date of mailing (day/month/year) 28 December 2000 (28.12.00)	
Applicant's or agent's file reference P/61695/PC	**IMPORTANT NOTICE**

International application No.	**International filing date** (day/month/year)	**Priority date** (day/month/year)
PCT/GB00/02188	07 June 2000 (07.06.00)	19 June 1999 (19.06.99)

Applicant
MARCONI CASWELL LIMITED et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   AU,KP,KR,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CN,CR,CU,CZ,DE,DK,DM,EA,EE,EP,ES,FI,GB,GD,
   GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,
   NO,NZ,OA,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW
   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on
   28 December 2000 (28.12.00) under No. WO 00/79636

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, **a demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer
J. Zahra

Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

From the INTERNATIONAL BUREAU

To:

TOLFREE, Roger, Keith
Marconi Intellectual Property
Waterhouse Lane
Chelmsford
Essex CM1 2QX
ROYAUME-UNI

INFORMATION CONCERNING ELECTED OFFICES NOTIFIED OF THEIR ELECTION

(PCT Rule 61.3)

Date of mailing (day/month/year) 16 March 2001 (16.03.01)	
Applicant's or agent's file reference P/61695.WOP/	**IMPORTANT INFORMATION**

International application No.	**International filing date** (day/month/year)	**Priority date** (day/month/year)
PCT/GB00/02188	07 June 2000 (07.06.00)	19 June 1999 (19.06.99)

Applicant
MARCONI CASWELL LIMITED et al

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

   AP :GH,GM,KE,LS,MW,MZ,SD,SL,SZ,TZ,UG,ZW
   EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
   National :AU,BG,CA,CN,CZ,DE,IL,JP,KP,KR,MN,NO,NZ,PL,RO,RU,SE,SK,US

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

   EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
   OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
   National :AE,AL,AM,AT,AZ,BA,BB,BR,BY,CH,CR,CU,DK,DM,EE,ES,FI,GB,GD,GE,GH,
   GM,HR,HU,ID,IN,IS,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MW,MX,PT,SD,
   SG,SI,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW

3. The applicant is reminded that he must enter the "national phase" **before the expiration of 30 months from the priority date** before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing , if prescribed, a translation of the international application (Article 39(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

   Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

   The entry into the European regional phase is postponed **until 31 months from the priority date** for all States designated for the purposes of obtaining a European patent.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer:

Juan Cruz

Telephone No. (41-22) 338.83.38

Fig.1(a).

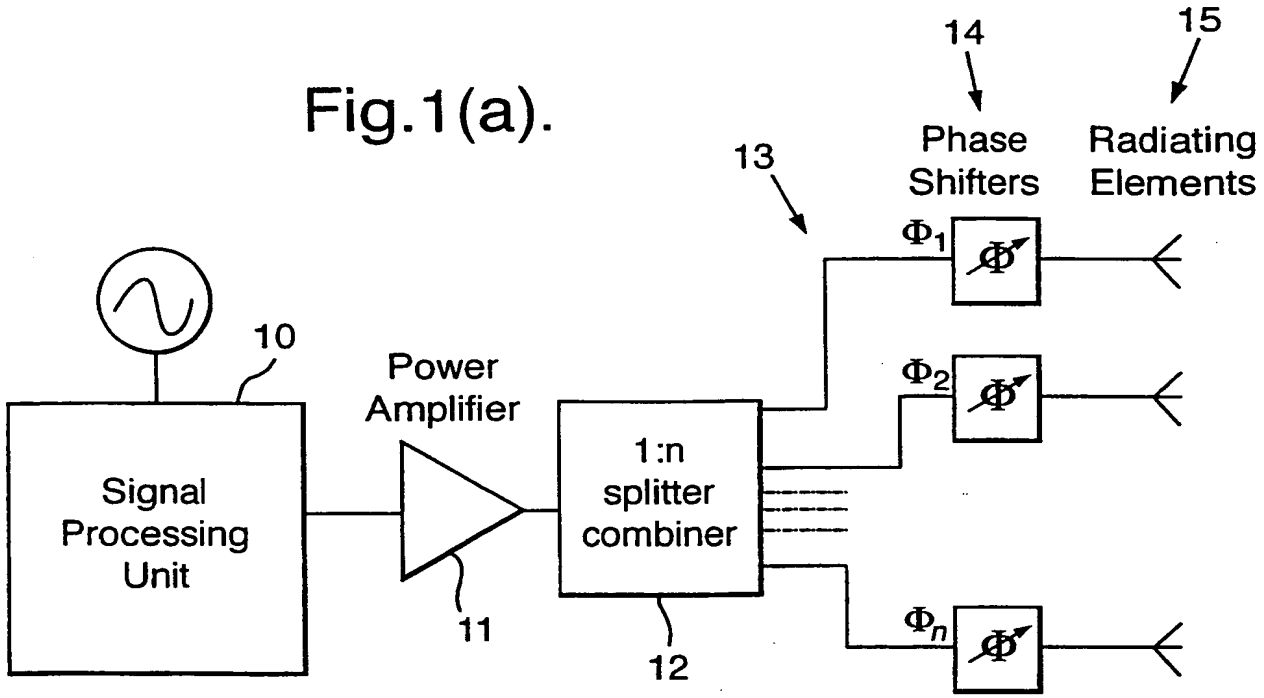


Fig.1(b).

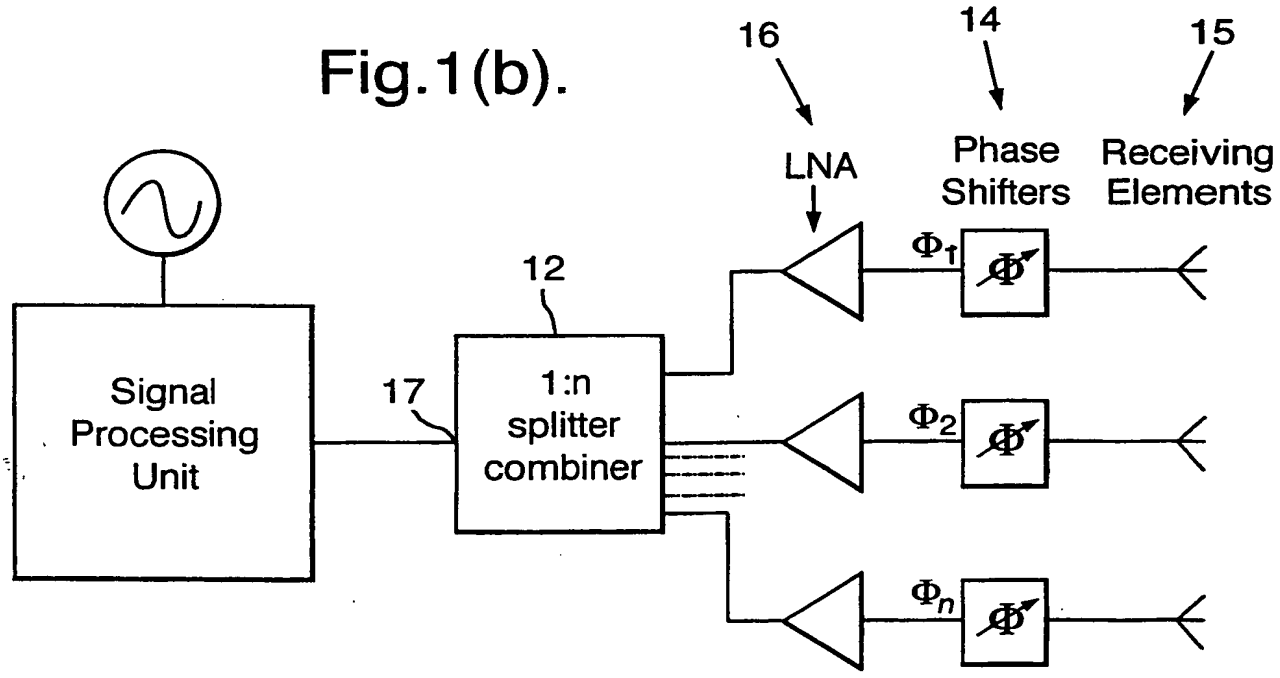


Fig.2.

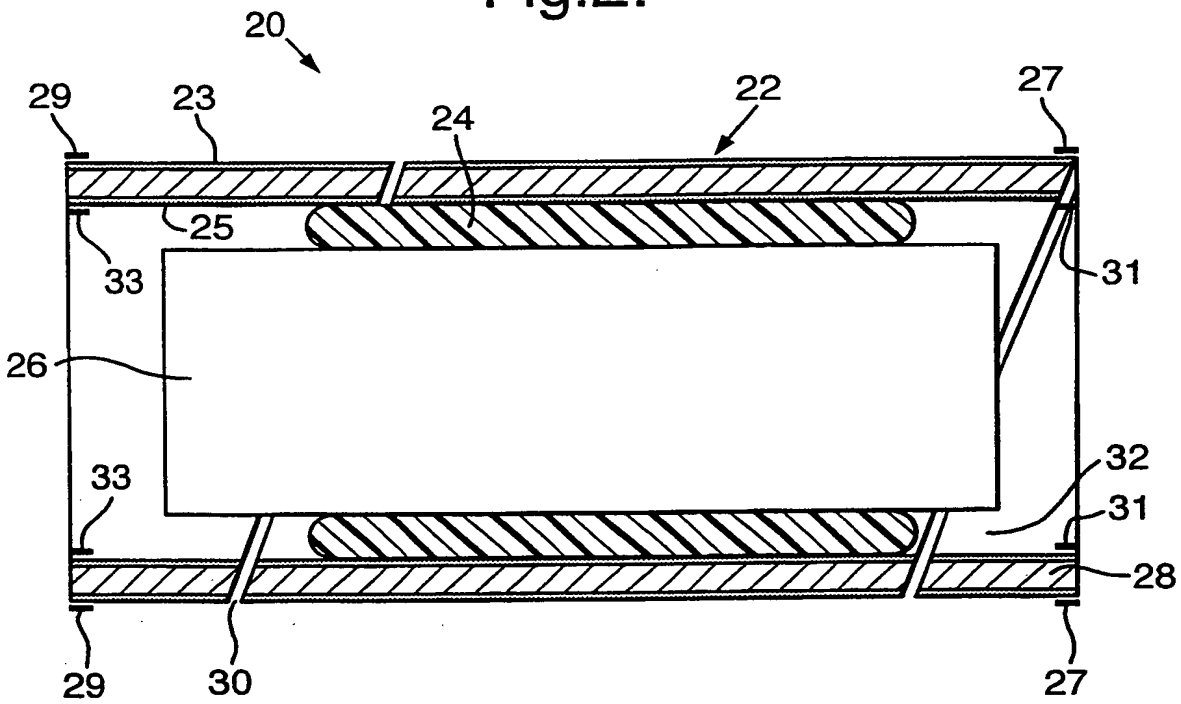


Fig.3(a).

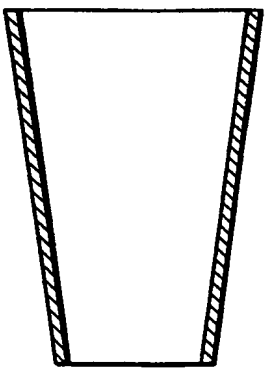


Fig.3(b).

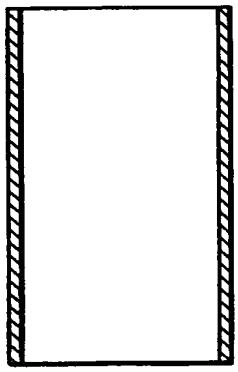


Fig.3(c).

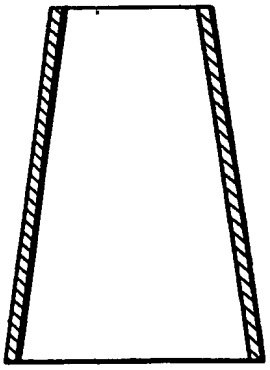
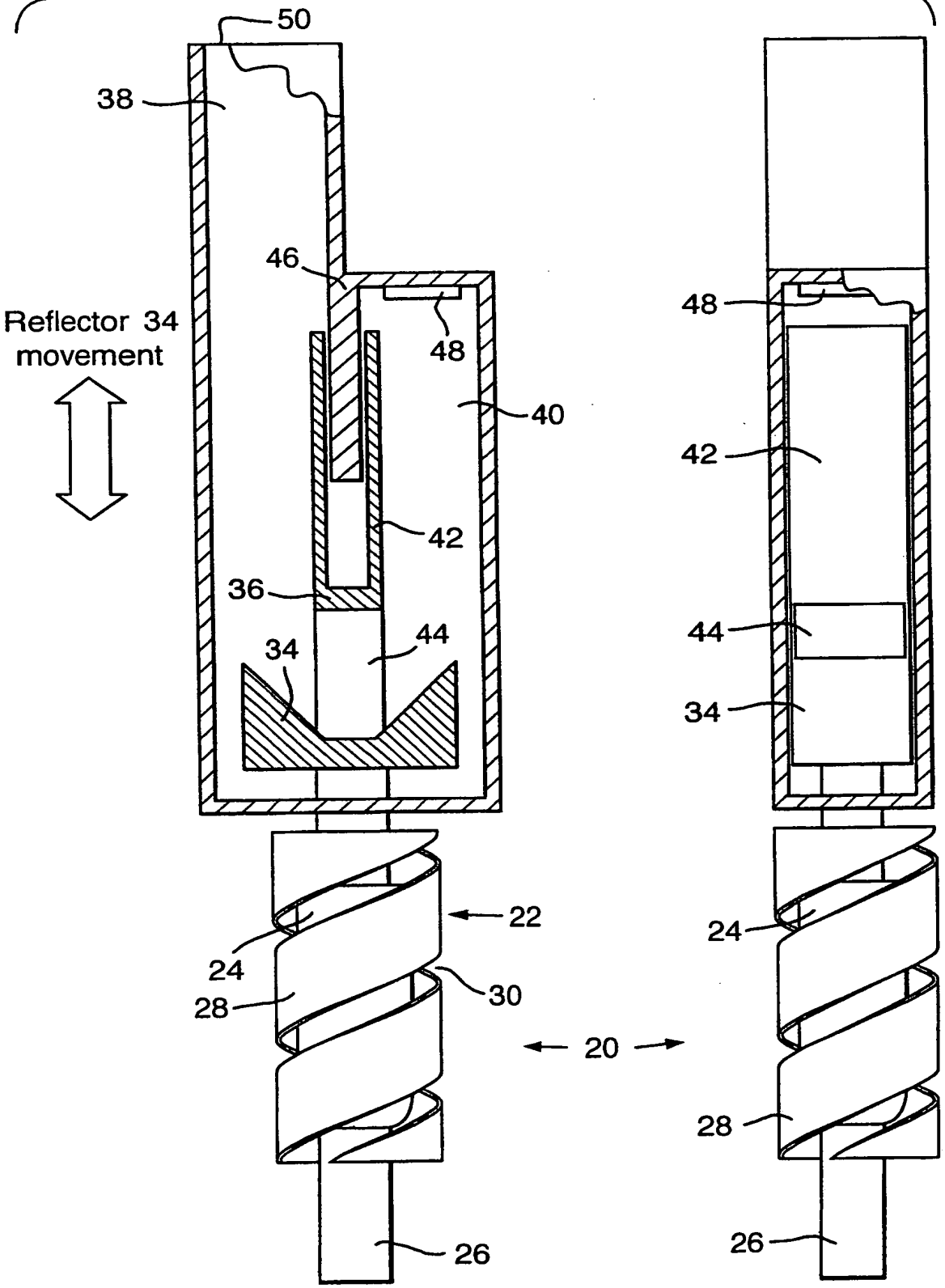


Fig.4.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Reflector 34 movement
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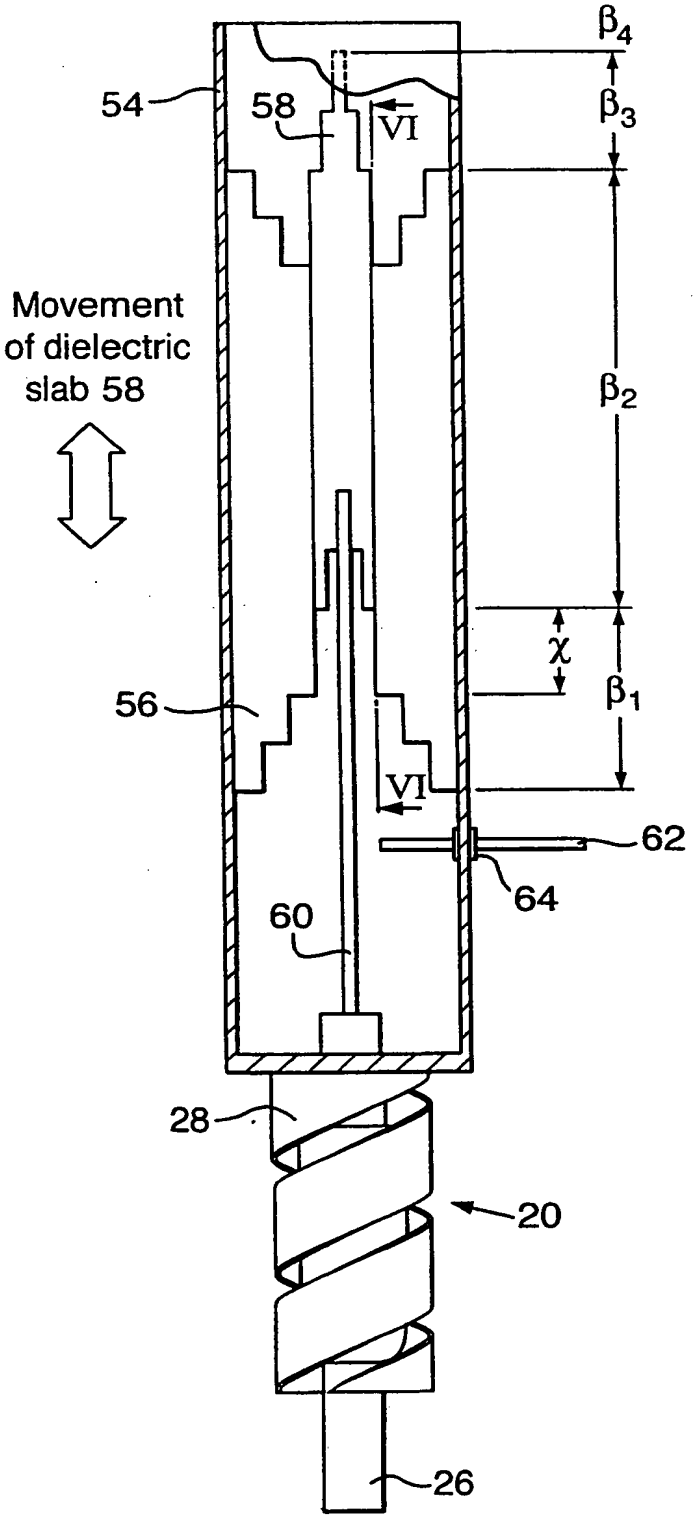
Fig.5.


β4
β3
β2
β1
χ
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VI
Movement of dielectric slab 58
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VI
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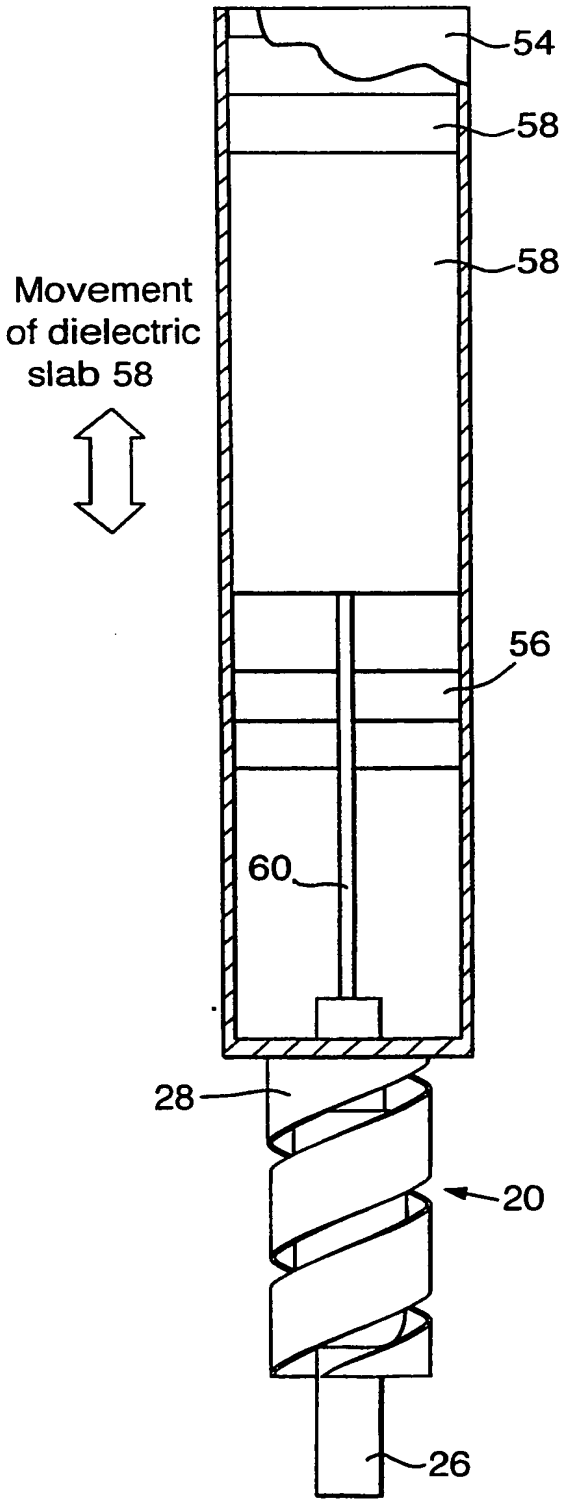
Fig.6.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Movement of dielectric slab 58
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Fig.7.

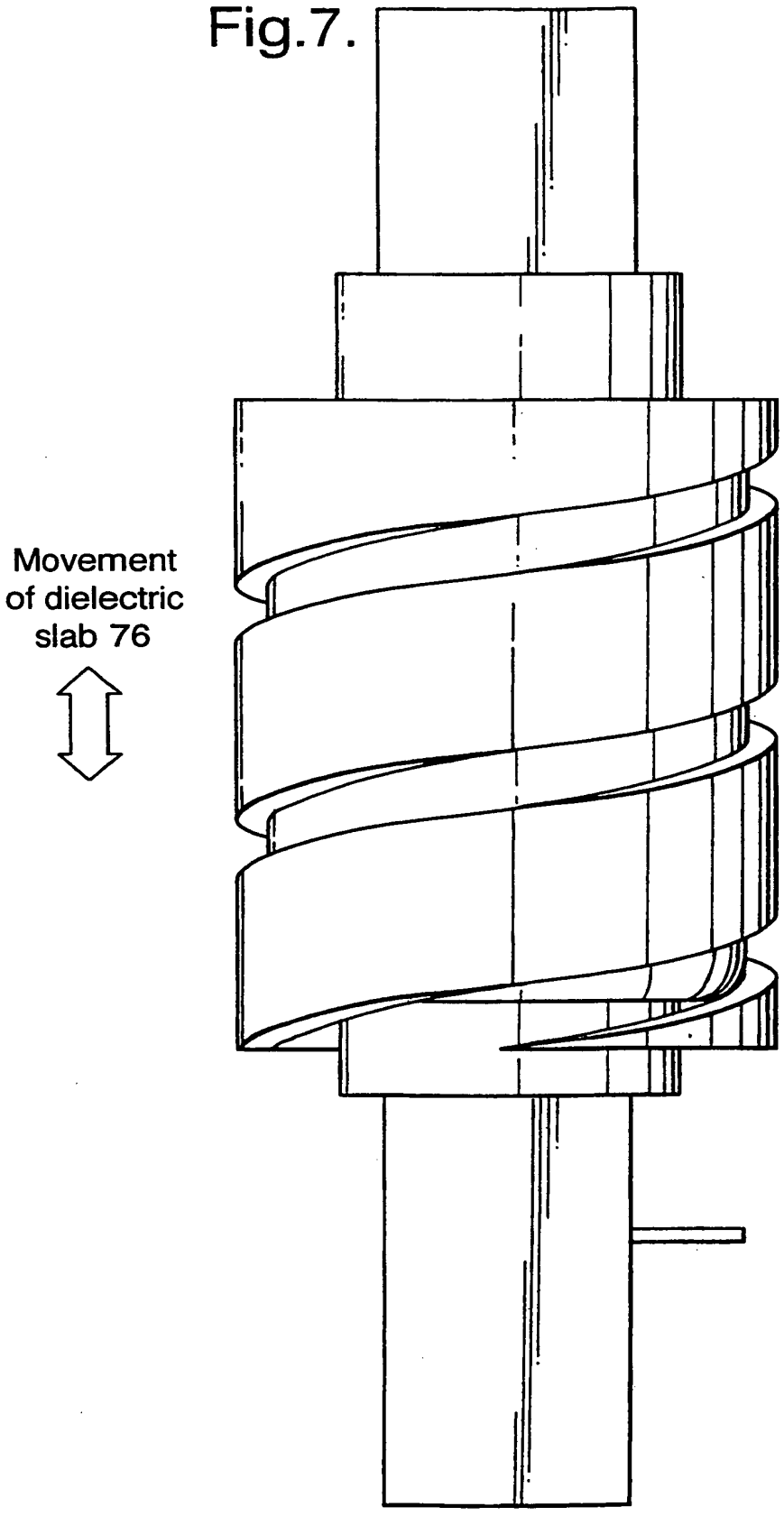
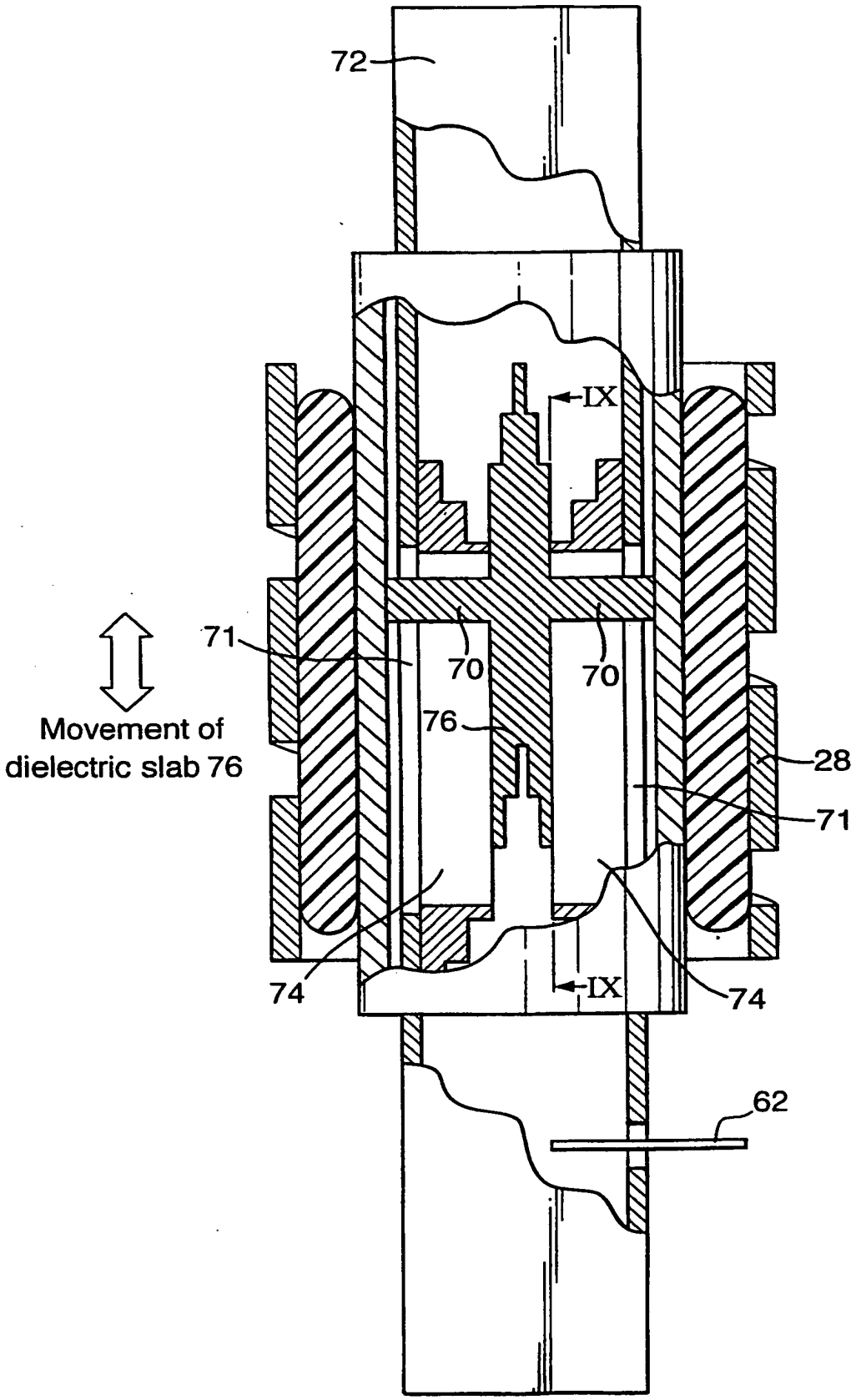


Fig.8.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IX
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IX
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Movement of
dielectric slab 76

Fig.9.

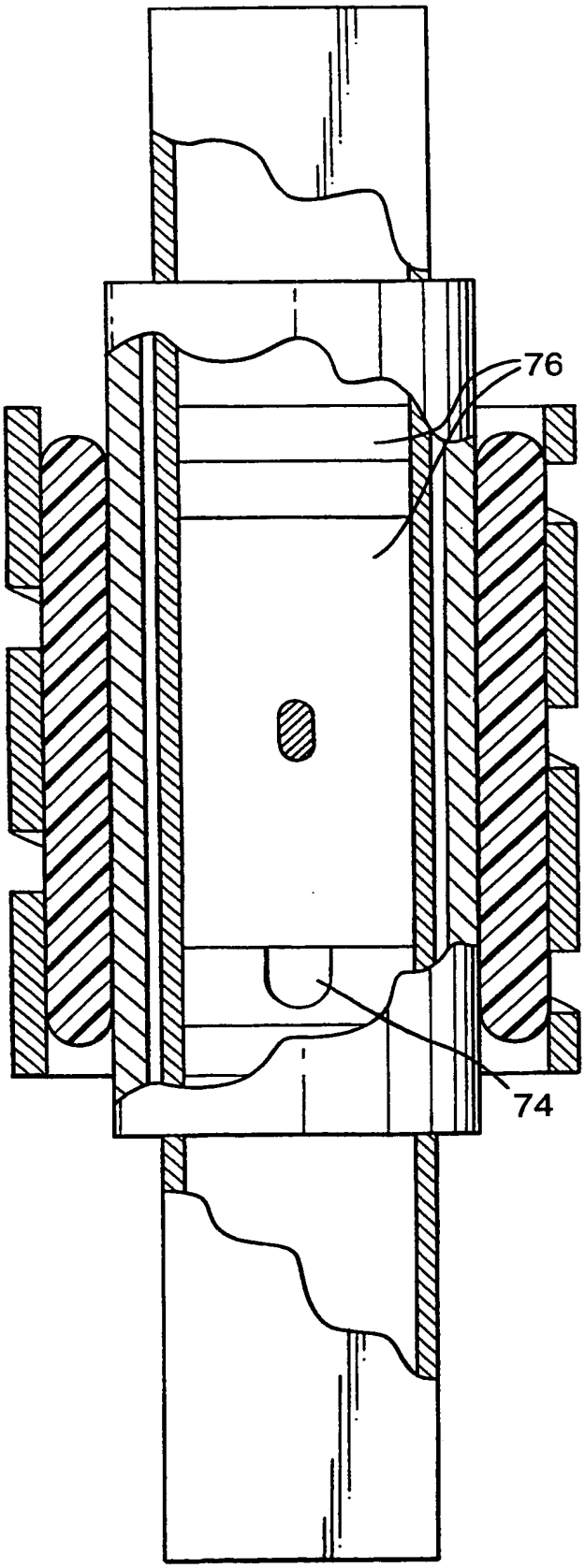

Fig.10.

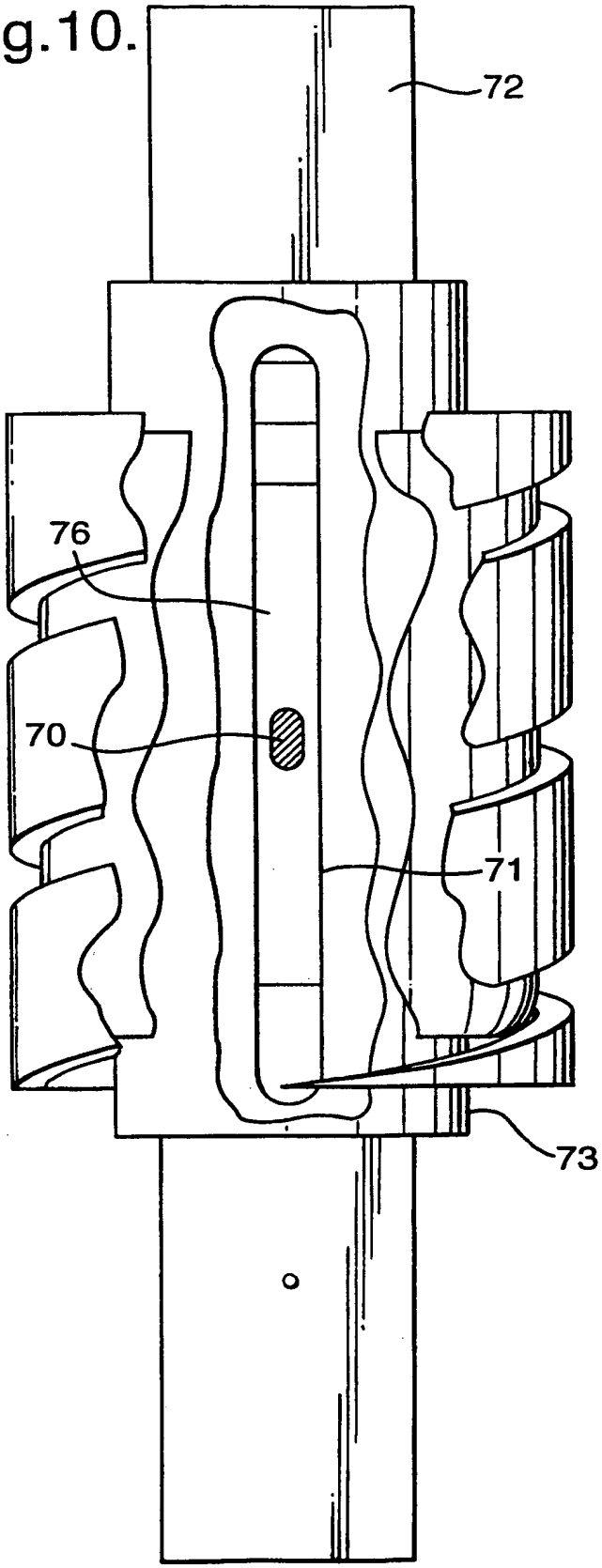

Fig.11.

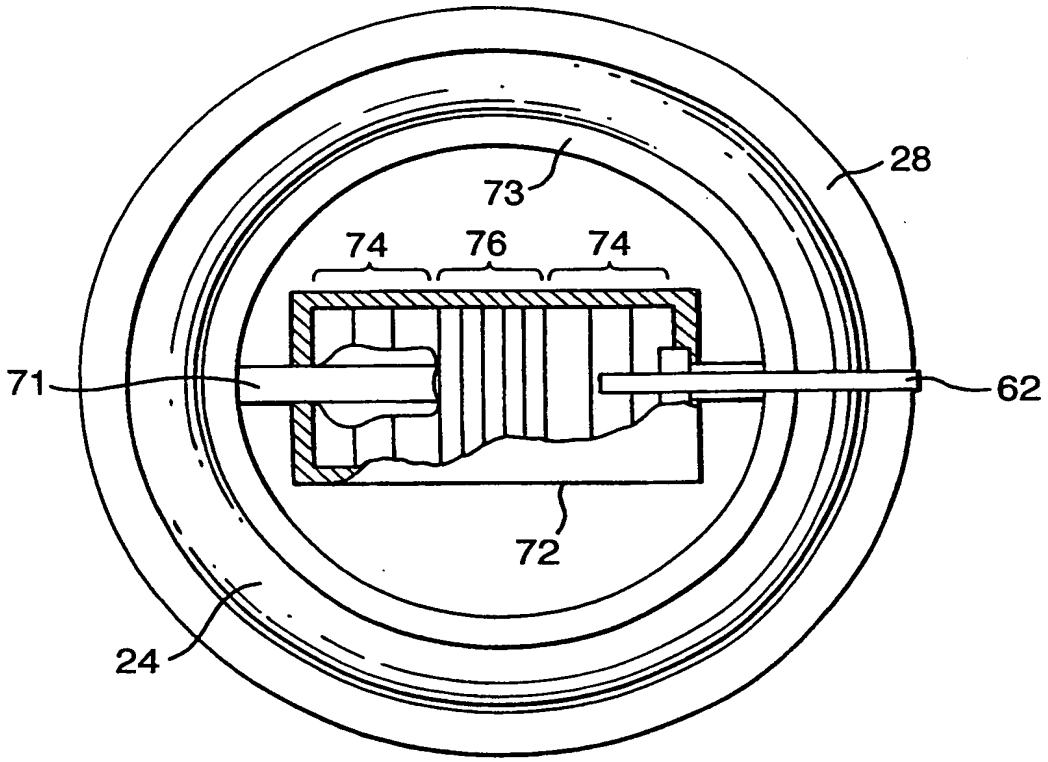

Fig.12.